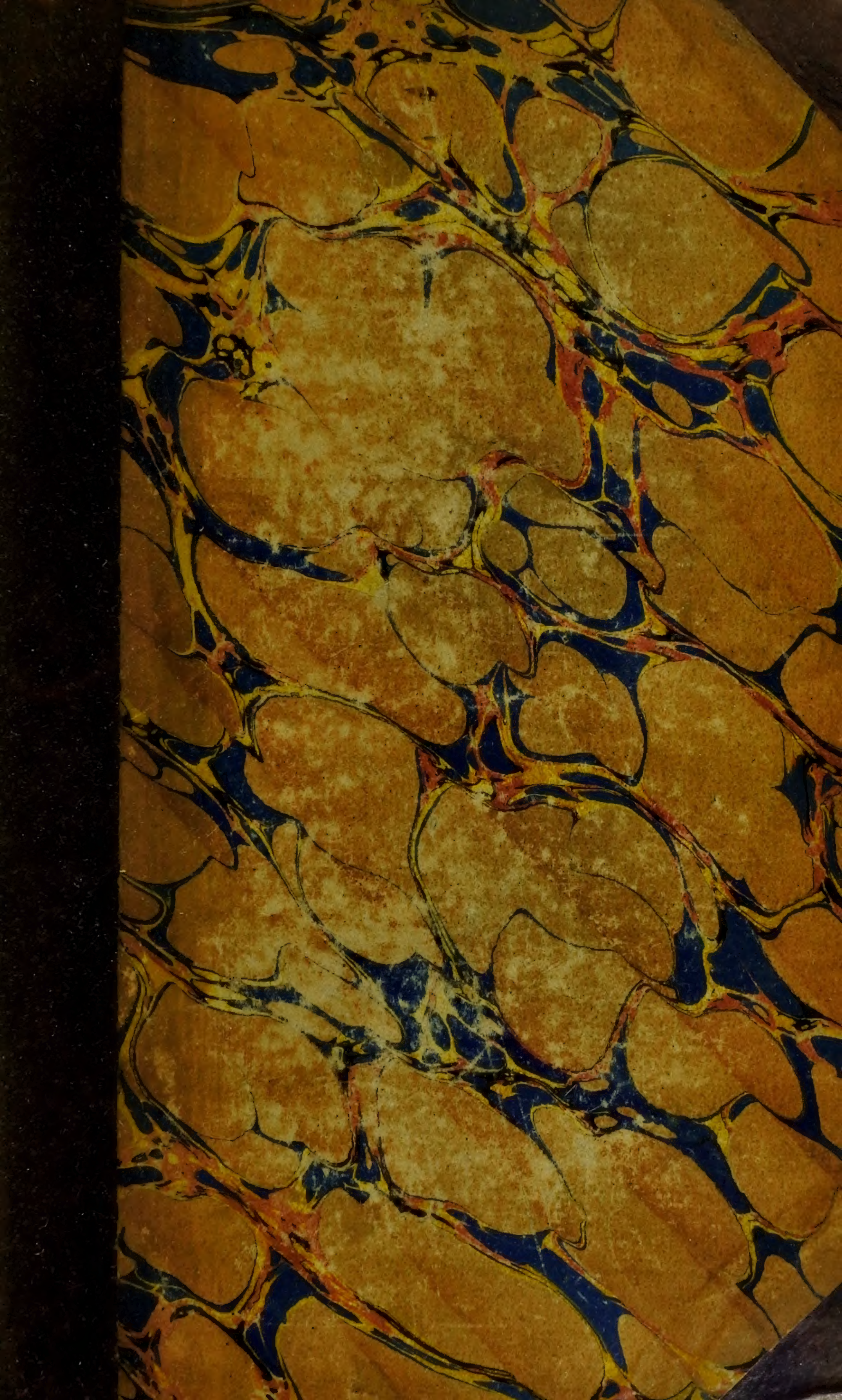


ELEMENTS

OF

CHEMISTRY,

IN A

NEW SYSTEMATIC ORDER,

CONTAINING ALL THE

MODERN DISCOVERIES.

ILLUSTRATED WITH THIRTEEN COPPERPLATES.

BY

M. LAVOISIER,

[illegible]

TRANSLATED FROM THE FRENCH

BY ROBERT KERR, F.R. & A. SS. EDIN.

Member of the Royal College of Surgeons, and of the Royal Physical Society of Edinburgh.

SIXTH EDITION,

WITH

NOTES, TABLES, AND CONSIDERABLE ADDITIONS.

IN TWO VOLUMES.

VOL. II.

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ELEMENTS

OF

CHEMISTRY.

PART III.

Deſcription of the Inſtruments and Operations of Chemiſtry.

INTRODUCTION.

IN the two former parts of this work, I deſignedly avoided being particular in deſcribing the manual operations of chemiſtry; becauſe I had found from experience, that in a work appropriated to reaſoning, minute deſcriptions of proceſſes and of plates interrupt the chain of ideas, and render the neceſſary attention both difficult and tedious to the reader. On the other hand, if I had confined myſelf to the ſummary deſcriptions hitherto given, beginners could have only acquired very vague concep-

tions of practical chemiſtry from my work, and muſt have wanted both confidence and intereſt in operations they could neither repeat nor thoroughly comprehended. This want could not have been ſupplied from books; for, beſides that there are not any which deſcribe the modern inſtruments and experiments ſufficiently at large, any work that could have been conſulted would have preſented theſe things under a very different order of arrangement, and in a different chemical language, which muſt greatly tend to injure the main object of my performance.

Influenced by theſe motives, I determined to reſerve, for a third part of my work, a ſummary deſcription of all the inſtruments and manipulations relative to elementary chemiſtry. I conſider it as better placed at the end than at the beginning of the book; becauſe, otherwiſe, I muſt have been obliged to ſuppoſe the reader converſant with circumſtances which a beginner cannot know, and to become acquainted with which he muſt have previouſly read the elementary part. The whole of this third part may, therefore, be conſidered as reſembling the explanations of plates, which are uſually placed at the end of academic memoirs, that they may not interrupt the connection of the text, by lengthened deſcription.

Though

Though I have taken great pains to render this part clear and methodical, and have not omitted any effential inftrument or apparatus, I am far from pretending by it to fet afide the neceffity of attendance upon lectures and laboratories, for fuch as wifh to acquire accurate knowledge of the fcience of chemiftry. Thefe fhould familiarize themfelves to the employment of apparatus, and to the performance of experiments by actual experience. *Nihil eft in intellectu quod non prius fuerit in fenfu*, the motto which the celebrated Rouelle caufed to be painted in large characters on a confpicuous part of his laboratory, is an important truth never to be loft fight of either by teachers or ftudents of chemiftry.

Chemical operations may be naturally divided into feveral claffes, according to the purpofes they are intended for performing. Some may be confidered as purely mechanical, fuch as the determination of the weight and bulk of bodies, trituration, levigation, fearching or fifting, wafhing, filtration, &c. Others may be confidered as real chemical operations, becaufe they are performed by means of chemical powers and agents; fuch are folution, fufion, &c. Some of thefe are intended for feparating the elements of bodies from each other, fome for reuniting thefe elements together, and fome, as combuftion, pro-

duce both theſe effects during the ſame proceſs.

Without rigourouſly endeavouring to follow the above method, I mean to give a detail of the chemical operations in ſuch order of arrangement as ſeems beſt calculated for conveying inſtruction. I ſhall be more particular in deſcribing the apparatus connected with modern chemiſtry, becauſe theſe are hitherto little known by men who have devoted much of their time to chemiſtry, and even by many profeſſors of the ſcience.

CHAP.

CHAP. I.

Of the Inſtruments neceſſary for determining the Abſolute and Specific Gravities of Solid and Liquid Bodies.

THE beſt method hitherto known for determining the quantities of ſubſtances ſubmitted to chemical experiment, or reſulting from them, is by means of accurately conſtructed beams and ſcales, with properly regulated weights; which well-known operation is called *weighing*. The denomination and quantity of the weight uſed as an unit or ſtandard for this purpoſe are extremely arbitrary, and vary, not only in different kingdoms, but even in different provinces of the ſame kingdom, and in different cities of the ſame province. This variation is of infinite conſequence to be well underſtood in commerce and in the arts; but, in chemiſtry, it is of no moment what particular denomination of weight be employed, provided the reſults of experiments be expreſſed in convenient fractions of the ſame denomination. For this purpoſe, until all the weights uſed in ſociety be reduced to the ſame ſtandard, it will be ſufficient for chemiſts, in different parts, to uſe the common pound

of their own country, as the unit or ftandard, and to exprefs all its fractional parts in decimals, inftead of the arbitrary divifions now in ufe. By this method the chemifts of all countries will be thoroughly underftood by each other; as, although the abfolute weights of the ingredients and products cannot be known, they will readily, and without calculation, be able to determine the relative proportions of thefe to each other with the utmoft accuracy; fo that in this way we fhall be poffeffed of an univerfal language for this part of chemiftry.

With this view I have long projected to have the pound divided into decimal fractions, and I have of late fucceeded, through the affiftance of Mr Fourche, balance-maker at Paris, who has executed it for me with great accuracy and judgment. I recommend to all who carry on experiments to procure fimilar divifions of the pound, which they will find both eafy and fimple in its application, with a very fmall knowledge of decimal fractions *.

As

* Mr Lavoifier gives, in this part of his work, very accurate directions for reducing the common fubdivifions of the French pound into decimal fractions, and *vice verfa*, by means of tables, fubjoined to this [illegible]d part. As thefe inftructions, and the table, would be ufelefs to the Britifh chemift, from the difference between the fubdivifions of the French and Troy pounds, I have omitted them, but have

As the usefulness and accuracy of chemistry depend entirely upon the determination of the weights of the ingredients and products, both before and after experiments, too much precision cannot be employed in this part of the subject; and, for this purpose, we must be provided with good instruments. As we are often obliged, in chemical processes, to ascertain, within a grain or less, the tare or weight of large and heavy instruments, we must have beams made with peculiar nicety by accurate workmen, and these must always be kept apart from the laboratory, in some place where the vapours of acids, or other corrosive liquors, cannot have access, otherwise the steel will rust, and the accuracy of the balance be destroyed. I have three sets, of different sizes, made by Mr Fontin with the utmost nicety, and, excepting those made by Mr Ramsden of London, I do not think any can compare with them for precision and sensibility. The largest of these is about three feet long in the beam for large weights, up to fifteen or twenty pounds; the second, for weights of eigh-

 teen

have subjoined in the appendix accurate rules for converting the one denomination into the other, together with tables for reducing the various divisions of our Troy pound into decimals, and for converting these decimals into the ordinary divisions.—T.

teen or twenty ounces, is exact to a tenth part of a grain; and the ſmalleſt, calculated only for weighing about one dram, is ſenſibly affected by the five hundredth part of a grain.

Beſides theſe nicer balances, which are only uſed for experiments of reſearch, we muſt have others of leſs value for the ordinary purpoſes of the laboratory. A large iron balance, capable of weighing forty or fifty pounds, within half a dram; one of a middle ſize, which may aſcertain eight or ten pounds, within ten or twelve grains; and a ſmall one, by which about a pound may be determined within one grain.

We muſt likewiſe be provided with weights divided into their ſeveral fractions, both vulgar and decimal, with the utmoſt nicety, and verified by means of repeated and accurate trials in the niceſt ſcales; and it requires ſome experience, and to be accurately acquainted with the different weights, to be able to uſe them properly. The beſt way of preciſely aſcertaining the weight of any particular ſubſtance, is to weigh it twice, once with the decimal diviſions of the pound, and another time with the common ſubdiviſions or vulgar fractions, and by comparing theſe, we attain the utmoſt accuracy.

By the ſpecific gravity of any ſubſtance, is underſtood the quotient of its abſolute weight divided by its magnitude, or, what is the ſame, the weight of a determined bulk of any body.

The

The weight of a determinate magnitude of water has been generally aſſumed as unity for this purpoſe; and we expreſs the ſpecific gravity of gold, ſulphuric acid, &c. by ſaying, that gold is nineteen times, and ſulphuric acid twice the weight of water, and ſo of other bodies.

It is the more convenient to aſſume water as unity in ſpecific gravities, that the ſubſtances whoſe ſpecific gravity we wiſh to determine, are moſt commonly weighed in water for that purpoſe. Thus, if we wiſh to determine the ſpecific gravity of gold flattened under the hammer, and ſuppoſing the piece of gold to weigh 4898½ *grs.* in the air *, it is ſuſpended by means of a fine metallic wire under the ſcale of a hydroſtatic balance, ſo as to be entirely immerſed in water, and again weighed. The piece of gold in Mr Briſſons experiment loſt by this means 253 *grs.*; and as it is evident that the weight loſt by a body weighed in water is preciſely equal to the weight of the water diſplaced, or to that of an equal volume of water, we may conclude, that, in equal magnitudes, gold weighs 4898½ *grs.* and water 253 *grs.* which, reduced to unity, gives 1.0000 as the ſpecific gravity of water, and 19.3617 for that of gold. We may operate in the ſame manner with

* Vide Mr Briſſons Eſſay upon Specific Gravity, p. 5. —A.

with all ſolid ſubſtances. We have, however, rarely any occaſion, in chemiſtry, to determine the ſpecific gravity of ſolid bodies, unleſs when operating upon alloys or metallic glaſſes; but we have very frequent neceſſity to aſcertain that of fluids, as it is often the only means of judging of their purity or degree of concentration.

This object may be very fully accompliſhed, with the hydroſtatic balance, by weighing a ſolid body, ſuch, for example, as a little ball of rock cryſtal ſuſpended by a very fine gold wire, firſt in the air, and afterwards in the fluid whoſe ſpecific gravity we wiſh to diſcover. The weight loſt by the cryſtal, when weighed in the liquor, is equal to that of an equal bulk of the liquid. By repeating this operation ſucceſſively in water and different fluids, we can very readily aſcertain, by a ſimple and eaſy calculation, the relative ſpecific gravities of theſe fluids, either with reſpect to each other or to water. This method is not, however, ſufficiently exact, or, at leaſt, is rather troubleſome, from its extreme delicacy, when uſed for liquids differing but little in ſpecific gravity from water; ſuch, for inſtance, as mineral waters, or any other water containing very ſmall portions of ſalt in ſolution.

In ſome operations of this nature, which have not hitherto been made public, I employed an inſtrument of great ſenſibility for this pur-

poſe

poſe with great advantage. It conſiſts of a hollow cylinder, *A b c f*, Pl. VII. fig. 6. of braſs, or rather of ſilver, loaded at its bottom, *b c f*, with tin, as repreſented ſwimming in a jug of water, *l m n o*. To the upper part of the cylinder is attached a ſtalk of ſilver-wire, not more than three-fourths of a line in diameter, ſurmounted by a little cup *d*, intended for containing weights; upon the ſtalk a mark is made at *g*, the uſe of which we ſhall preſently explain. This cylinder may be made of any ſize; but, to be accurate, ought at leaſt to diſplace four pounds of water. The weight of tin with which this inſtrument is loaded ought to be ſuch as will make it remain almoſt in equilibrium in diſtilled water, and ſhould not require more than half a dram, or a dram at moſt, to make it ſink to *g*.

We muſt firſt determine, with great preciſion, the exact weight of the inſtrument, and the number of additional grains requiſite for making it ſink, in diſtilled water of a determinate temperature, to the mark: We then perform the ſame experiment upon all the fluids of which we wiſh to aſcertain the ſpecific gravities, and by means of calculation, reduce the obſerved differences to a common ſtandard of cubic feet, pints, or pounds, or of decimal fractions, comparing them with water. This method, joined to experiments with certain re-

agents,

agents *, is one of the beſt for determining the quality of waters, and is even capable of pointing out differences which eſcape the moſt accurate chemical analyſis. I ſhall, at ſome future period, give an account of a very extenſive ſet of experiments which I have made upon this ſubject.

Theſe metallic hydrometers are only to be uſed for determining the ſpecific gravities of ſuch waters as contain only neutral ſalts or alkaline ſubſtances; and they may be conſtructed with different degrees of ballaſt for alcohol and other ſpirituous liquors. When the ſpecific gravities of acid liquors are to be aſcertained, we muſt uſe a glaſs hydrometer, as repreſented Pl. VII. fig. 14 †. This conſiſts of a hollow cylinder of glaſs, *a b c f*, hermetically ſealed at its lower end, and drawn out at the upper extremity into a capillary tube *a*, ending in the little cup or baſon *d*. This inſtrument is ballaſted with more or leſs mercury, at the bottom of the cylinder, introduced through the tube, in proportion

* For the uſe of theſe reagents, ſee Bergmans excellent treatiſe upon the analyſis of mineral waters, in his Chemical and Phyſical Eſſays.—T.

† Previous to the year 1787, I have ſeen ſimilar glaſs hydrometers, made for Dr Black by B. Knie, a very ingenious artiſt in Edinburgh.—T.

portion to the weight of the liquor intended to be examined: We may introduce a ſmall graduated ſlip of paper into the tube *a d*; and, though theſe degrees do not exactly correſpond to the fractions of grains in the different liquors, they may be rendered very uſeful in calculation.

What is ſaid in this chapter may ſuffice, without farther enlargement, for indicating the means of aſcertaining the abſolute and ſpecific gravities of ſolids and fluids, as the neceſſary inſtruments are generally known, and may eaſily be procured: But, as the inſtruments I have uſed for meaſuring and weighing the gaſes are not any where deſcribed, I ſhall give a more detailed account of theſe in the following chapter.

CHAP.

CHAP. II.

Of Gazometry, or the Meaſurement of the Weight and Volume of Aëriform Subſtances.

SECT. I.

Deſcription of the Pneumato-chemical Apparatus.

THE French chemiſts have of late applied the name of *pneumato-chemical apparatus* to the very ſimple and ingenious contrivance, invented by Dr Prieſtley, which is now indiſpenſibly neceſſary to every laboratory. This conſiſts of a wooden trough, of larger or ſmaller dimenſions as is thought convenient, lined with plate-lead or tinned copper, as repreſented in perſpective, Pl. V. Fig. 1.—In Fig. 2. the ſame trough or ciſtern is ſuppoſed to have two of its ſides cut away, to ſhow its interior conſtruction more diſtinctly. In this apparatus, we diſtinguiſh between the ſhelf ABCD, Fig. 1. and 2. and the bottom or body of the ciſtern FGHI, Fig.

Fig. 2. The jars or bell-glaſſes are filled with water in this deep part, and, being turned with their mouths downwards, are afterwards ſet upon the ſhelf ABCD, as ſhewn Pl. X. Fig. 1. F.— The upper parts of the ſides of the ciſtern above the level of the ſhelf are called the *rim* or *borders*.

The ciſtern ought to be filled with water, ſo as to ſtand at leaſt an inch and a half deep over the ſhelf, and it ſhould be of ſuch dimenſions as to admit of at leaſt one foot of water in every direction in the well, or ciſtern. The ſize above deſcribed is ſufficient for ordinary occaſions; but it is often convenient, and even neceſſary, to have more room; I would therefore adviſe ſuch as intend to employ themſelves uſefully in chemical experiments, to have this apparatus made of conſiderable magnitude, when their place of operating will allow. The well of my principal ciſtern holds four cubical feet of water, and its ſhelf has a ſurface of fourteen ſquare feet, yet, in ſpite of this ſize, which I at firſt thought immoderate, I am often ſtraitened for room.

In laboratories, where a conſiderable number of experiments are performed, it is neceſſary to have ſeveral leſſer ciſterns, beſides the large one, which may be called the *general magazine*; and even ſome portable ones, which may be moved when neceſſary, near a furnace, or wherever they may be wanted. There are likewiſe ſome operations which dirty the water of the apparatus,

tus, and therefore require to be carried on in ciſterns by themſelves.

It were doubtleſs conſiderably cheaper to uſe ciſterns of wood, ſimply dove-tailed, or iron-bound tubs, inſtead of being lined with lead or copper; and in my firſt experiments I uſed them made in that way, but I ſoon diſcovered their inconvenience. If the water be not always kept at the ſame level, ſuch of the dovetails as are left dry ſhrink, and, when more water is added, it eſcapes through the joints, and runs out.

We employ cryſtal-jars or bell-glaſſes, Pl. V. Fig. 9. A. for containing the glaſſes in this apparatus; and, for tranſporting theſe, when full of gas, from one ciſtern to another, or for keeping them in reſerve when the ciſtern is too full, we make uſe of a flat diſh BC, ſurrounded by a ſtanding up rim or border, with two handles DE for carrying it by.

After ſeveral trials of different materials, I have found marble the beſt ſubſtance for conſtructing the mercurial pneumato-chemical apparatus, as it is perfectly impenetrable by mercury, and is not liable, like wood, to ſeparate at the junctures, or to allow the mercury to eſcape through chinks; neither does it run the riſk of breaking, like glaſs, ſtone-ware, or porcelain. Take a block of marble BCDE, Plate V. Fig. 3. and 4. about two feet long, 15 or 18 inches broad,

broad and ten inches thick, and cauſe it to be hollowed out, as at *m n*, Fig. 5. about four inches deep, as a reſervoir for the mercury; and, to be able more conveniently to fill the jars, cut the gutter T V, Fig. 3. 4. and 5. at leaſt four inches deeper; and as this trench may ſometimes prove troubleſome, it is made capable of being covered at pleaſure by thin boards, which ſlip into the grooves *x y*, Fig. 5. I have two marble ciſterns upon this conſtruction, of different ſizes, by which I can always employ one of them as a reſervoir of mercury, which it preſerves with more ſafety than any other veſſel, being neither ſubject to overturn, nor to any other accident. We operate with mercury in this apparatus exactly as with water in the one before deſcribed; but the bell-glaſſes muſt be of ſmaller diameters, and much ſtronger; or we may uſe glaſs-tubes, having their mouths widened, as in Fig. 7.; theſe are called *eudiometers* by the glaſs-men who ſell them. One of the bell-glaſſes is repreſented Fig. 5. A. ſtanding in its place, and what is called a jar is engraved at Fig. 6.

The mercurial pneumato-chemical apparatus is neceſſary in all experiments wherein the diſengaged gaſes are capable of being abſorbed by water, as is frequently the caſe, eſpecially in all combinations, excepting thoſe of metals, in fermentation, &c.

SECT. II.

Of the Gazometer.

I give the name of *gazometer* to an inſtrument which I invented, and cauſed to be conſtructed, for the purpoſe of a kind of bellows, which might furniſh an uniform and continued ſtream of oxygen gas in experiments of fuſion. Mr Meuſnier and I have ſince made very conſiderable corrections and additions, having converted it into what may be called an *univerſal inſtrument*, without which it is hardly poſſible to perform moſt of the very exact experiments. The name we have given the inſtrument indicates its intention for meaſuring the volume or quantity of gas ſubmitted to it for examination.

It conſiſts of a ſtrong iron beam, DE, Pl. VIII. Fig. 1, three feet long, having at each end, D, and E, a ſegment of a circle, likewiſe ſtrongly conſtructed of iron, and very firmly joined. Inſtead of being poiſed as in ordinary balances, this beam reſts, by means of a cylindrical axis of poliſhed ſteel, F, Fig. 9. upon two large moveable braſs friction-wheels, by which the reſiſtance to its motion from friction is conſiderably diminiſhed, being converted into friction of the ſecond order. As an additional precau-

tion,

tion, the parts of theſe wheels which ſupport the axis of the beam are covered with plates of poliſhed rock-cryſtal. The whole of this machinery is fixed to the top of the ſolid column of wood BC, Fig. 1. To one extremity D of the beam, a ſcale P for holding weights is ſuſpended by a flat chain, which applies to the curvature of the arc *n*D*o*, in a groove made for the purpoſe. To the other extremity E of the beam is applied another flat chain, *i k m*, ſo conſtructed, as to be incapable of lengthening or ſhortening, by being leſs or more charged with weight; to this chain, an iron trivet, with three branches, *a i*, *c i*, and *b i*, is ſtrongly fixed at *i*, and theſe branches ſupport a large inverted jar A, of hammered copper, about 18 inches diameter, and 20 inches deep. The whole of this machine is repreſented in perſpective, Pl. VIII. Fig. 1.; and Pl. IX. Fig. 2. and 4. give perpendicular ſections which ſhew its interior ſtructure.

Round the bottom of the jar, on its outſide, is fixed, Pl. IX. Fig. 2. a border divided into compartments 1, 2, 3, 4, &c. intended to receive leaden-weights ſeparately repreſented 1, 2, 3, Fig. 3. Theſe are intended for increaſing the weight of the jar when a conſiderable preſſure is requiſite, as will be afterwards explained, though ſuch neceſſity ſeldom occurs. The cylindrical jar A is entirely open below, *d e*, Pl. IX. Fig. 4.; but is cloſed above with a cop-

per lid, *a b c*, open at *b f*, and capable of being ſhut by the cock *g*. This lid, as may be ſeen by inſpecting the figures, is placed a few inches within the top of the jar, to prevent the jar from being ever entirely immerſed in the water, and covered over: were I to have this inſtrument made over again, I ſhould cauſe the lid to be conſiderably more flattened, ſo as to be almoſt level. This jar or reſervoir of air is contained in the cylindrical copper-veſſel LMNO, Pl. VIII. Fig. 1. filled with water.

In the middle of the cylindrical veſſel LMNO, Pl. IX. Fig. 4. are placed two tubes *s t*, *x y*, which are made to approach each other at their upper extremities *t y*; theſe are made of ſuch a length as to riſe a little above the upper edge LM of the veſſel LMNO, and when the jar *abcde* touches the bottom NO, their upper ends enter about half an inch into the conical hollow *b*, leading to the ſtop-cock *g*.

The bottom of the veſſel LMNO, is repreſented Pl. IX. Fig. 3. in the middle of which a ſmall hollow hemiſpherical cap is ſoldered, which may be conſidered as the broad end of a funnel reverſed; the two tubes *s t*, *x y*, Fig. 4. are adapted to this cap at *s* and *x*, and by this means communicate with the tubes *mm*, *nn*, *oo*, *pp*, Fig. 3. which are fixed horizontally upon the bottom of the veſſel, and all of which terminate in, and are united by, the ſpherical cap *sx*. Three of theſe tubes are continued out of the veſſel as in

Pl.

Pl. VIII. Fig. 1. The first marked in that figure 1, 2, 3, is inserted at its extremity 3, by means of an intermediate stop-cock 4, to the jar V. which stands upon the shelf of a small pneumato-chemical apparatus GHIK, the inside of which is shewn Pl. IX. Fig. 1. The second tube is applied against the outside of the vessel LMNO from 6 to 7, is continued at 8, 9, 10, and at 11 is engaged below the jar V. The former of these tubes is intended for conveying gas into the machine, and the latter for conducting small quantities for trials under jars. The gas is made either to flow into or out of the machine, according to the degree of pressure it receives; and this pressure is varied at pleasure, by loading the scale P less or more, by means of weights. When gas is to be introduced into the machine, the pressure is taken off, or even rendered negative; but when gas is to be expelled, a pressure is made with such degree of force as is found necessary.

The third tube 12, 13, 14, 15, is intended for conveying air or gas to any necessary place or apparatus for combustions, combinations, or any other experiment in which it may be required.

To explain the use of the fourth tube, I must enter into some discussions. Suppose the vessel LMNO, Pl. VIII. Fig. 1. full of water, and the jar A partly filled with gas and partly with water; it is evident that the weights in the ba-

ſon P may be ſo adjuſted, as to occaſion an exact equilibrium between the weight of the baſon and of the jar, ſo that the external air ſhall not tend to enter into the jar, nor the gas to eſcape from it; and in this caſe the water will ſtand exactly at the ſame level both within and without the jar. On the contrary, if the weight in the baſon P be diminiſhed, the jar will then preſs downwards from its own gravity, and the water will ſtand lower within the jar than it does without; in this caſe, the included air or gas will ſuffer a degree of compreſſion above that experienced by the external air, exactly proportioned to the weight of a column of water, equal to the difference of the external and internal ſurfaces of the water.

From theſe reflections, Mr Meuſnier contrived a method of determining the exact degree of preſſure to which the gas contained in the jar is at any time expoſed. For this purpoſe, he employs a double glaſs ſyphon 19, 20, 21, 22, 23, firmly cemented at 19 and 23. The extremity 19 of this ſyphon communicates freely with the water in the external veſſel of the machine, and the extremity 23 communicates with the fourth tube at the bottom of the cylindrical veſſel, and conſequently, by means of the perpendicular tube *s t*, Pl. IX. Fig. 4. with the air contained in the jar. He likewiſe cements, at 16, Pl. VIII. Fig. 1. another glaſs-tube 16, 17, 18, which

communicates

communicates at 16 with the water in the exterior veſſel LMNO, and, at its upper end 18, is open to the external air.

By theſe ſeveral contrivances, it is evident that the water muſt ſtand in the tube 16, 17, 18, at the ſame level with that in the ciſtern LMNO; and, on the contrary, that, in the branch 19, 20, 21, it muſt ſtand higher or lower according as the air in the jar is ſubjected to a greater or leſſer preſſure than the external air. To aſcertain theſe differences, a braſs ſcale divided into inches and lines is fixed between theſe two tubes. It is readily conceived that, as air, and all other elaſtic fluids, muſt increaſe in weight by compreſſion, it is neceſſary to know their degree of condenſation to be enabled to calculate their quantities, and to convert the meaſure of their volumes into correſpondent weights; and this object is intended to be fulfilled by the contrivance now deſcribed.

But, to determine the ſpecific gravity of air or of gaſes, and to aſcertain their weight in a known volume, it is neceſſary to know their temperature, as well as the degree of preſſure under which they ſubſiſt; and this is accompliſhed by means of a ſmall thermometer, ſtrongly cemented into a braſs collet, which ſcrews into the lid of the jar A. This thermometer is repreſented ſeparately, Pl. VIII. Fig. 10. and in its place 24, 25, Fig. 1. and Pl. IX. Fig. 4. The bulb is

in the inſide of the jar A, and its graduated ſtalk riſes on the outſide of the lid.

The practice of gazometry would ſtill have laboured under great difficulties, without farther precautions than thoſe above deſcribed. When the jar A ſinks in the water of the ciſtern LMNO, it muſt loſe a weight equal to that of the water which it diſplaces; and conſequently the compreſſion which it makes upon the contained air or gas muſt be proportionally diminiſhed. Hence the gas furniſhed, during experiments from the machine, will not have the ſame denſity towards the end that it had at the beginning, as its ſpecific gravity is continually diminiſhing. This difference may, it is true, be determined by calculation; but this would have occaſioned ſuch mathematical inveſtigations as muſt have rendered the uſe of this apparatus both troubleſome and difficult. Mr Meuſnier has remedied this inconvenience by the following contrivance. A ſquare rod of iron, 26, 27, Pl. VIII. Fig. 1. is raiſed perpendicular to the middle of the beam DE. This rod paſſes through a hollow box of braſs 28, which opens, and may be filled with lead; and this box is made to ſlide alongſt the rod, by means of a toothed pinion playing in a rack, ſo as to raiſe or lower the box, and to fix it at ſuch places as is judged proper.

When the lever or beam DE ſtands horizontal,

tal, this box gravitates to neither ſide; but, when the jar A ſinks into the ciſtern LMNO, ſo as to make the beam incline to that ſide, it is evident the loaded box 28, which then paſſes beyond the center of ſuſpenſion, muſt gravitate to the ſide of the jar, and augment its preſſure upon the included air. This is increaſed in proportion as the box is raiſed towards 27, becauſe the ſame weight exerts a greater power in proportion to the length of the lever by which it acts. Hence, by moving the box 28 along the rod 26, 27, we can augment or diminiſh the correction it is intended to make upon the preſſure of the jar; and both experience and calculation ſhew that this may be made to compenſate very exactly for the loſs of weight in the jar at all degrees of preſſure.

I have not hitherto explained the moſt important part of the uſe of this machine, which is the manner of employing it for aſcertaining the quantities of the air or gas furniſhed during experiments. To determine this with the moſt rigorous preciſion, and likewiſe the quantity ſupplied to the machine from experiments, we fixed to the arc which terminates the arm of the beam E, Pl. VIII. Fig. 1. the braſs ſector *l m*, divided into degrees and half degrees, which conſequently moves in common with the beam; and the lowering of this end of the beam is meaſured by the fixed index 29, 30, which

which has a Nonius giving hundredth parts of a degree at its extremity 30.

The whole particulars of the different parts of the above-defcribed machine are reprefented in Pl. VIII. as follow.

Fig. 2. Is the flat chain invented by Mr Vaucanfon, and employed for fufpending the fcale or bafon P, Fig. 1.; but, as this lengthens or fhortens according as it is more or lefs loaded, it would not have anfwered for fufpending the jar A, Fig. 1.

Fig. 5. Is the chain *i k m*, which in Fig. 1. fuftains the jar A. This is entirely formed of plates of polifhed iron interlaced into each other, and held together by iron-pins. This chain does not lengthen in any fenfible degree, by any weight it is capable of fupporting.

Fig. 6. The trivet, or three-branched ftirrup, by which the jar A is hung to the balance, with the fcrew by which it is fixed in an accurately vertical pofition.

Fig. 3. The iron rod 26, 27, which is fixed perpendicular to the centre of the beam, with its box 28.

Fig. 7. & 8. The friction-wheels, with the plates of rock-cryftal Z, as points of contact by which the friction of the axis of the lever of the balance is avoided.

Fig.

Fig. 4. The piece of metal which ſupports the axis of the friction-wheels.

Fig. 9. The middle of the lever or beam, with the axis upon which it moves.

Fig. 10. The thermometer for determining the temperature of the air or gas contained in the jar.

When this gazometer is to be uſed, the ciſtern or external veſſel, LMNO, Pl. VIII. Fig. 1. is to be filled with water to a determinate height, which ſhould be the ſame in all experiments. The level of the water ſhould be taken when the beam of the balance ſtands horizontal; this level, when the jar is at the bottom of the ciſtern, is increaſed by all the water which it diſplaces, and is diminiſhed in proportion as the jar riſes to its higheſt elevation. We next endeavour, by repeated trials, to diſcover at what elevation the box 28 muſt be fixed, to render the preſſure equal in all ſituations of the beam. I ſhould have ſaid nearly, becauſe this correction is not abſolutely rigorous; and differences of a quarter, or even of half a line, are not of any conſequence. This height of the box 28 is not the ſame for every degree of preſſure, but varies according as this is of one, two, three, or more inches. All theſe ſhould be regiſtered with great order and preciſion.

We next take a bottle which holds eight or ten pints, the capacity of which is very accurately

rately determined by weighing the water it is capable of containing. This bottle is turned bottom upwards, full of water in the ciſtern of the pneumato-chemical apparatus GHIK, Fig. 1. and is ſet on its mouth upon the ſhelf of the apparatus, inſtead of the glaſs-jar V, having the extremity 11 of the tube 7, 8, 9, 10, 11, inſerted into its mouth. The machine is fixed at zero of preſſure, and the degree marked by the index 30 upon the ſector *m l* is accurately obſerved; then, by opening the ſtop-cock 8, and preſſing a little upon the jar A, as much air is forced into the bottle as fills it entirely. The degree marked by the index upon the ſector is now obſerved, and we calculate what number of cubical inches correſpond to each degree. We then fill a ſecond and third bottle, and ſo on, in the ſame manner, with the ſame precautions, and even repeat the operation ſeveral times with bottles of different ſizes, till at laſt, by accurate attention, we aſcertain the exact gage or capacity of the jar A, in all its parts; but it is better to have it formed at firſt accurately cylindrical; by which we avoid theſe calculations and eſtimates.

The inſtrument I have been deſcribing was conſtructed with great accuracy and uncommon ſkill by Mr Meignie junior, engineer and phyſical inſtrument-maker. It is a moſt valuable inſtrument, from the great number of purpoſes to which

which it is applicable; and, indeed, there are many experiments which are almoſt impoſſible to be performed without it. It becomes expenſive, becauſe, in many experiments, ſuch as the formation of water and of nitric acid, it is abſolutely neceſſary to employ two of the ſame machines. In the preſent advanced ſtate of chemiſtry, very expenſive and complicated inſtruments are become indiſpenſably neceſſary, for aſcertaining the analyſis and ſyntheſis of bodies, with the requiſite preciſion as to quantity and proportion; it is certainly proper to endeavour to ſimplify theſe, and to render them leſs coſtly; but this ought by no means to be attempted at the expence of their conveniency of application, and much leſs of their accuracy.

SECT. III.

Some other Methods of meaſuring the Volume of Gaſes.

The gazometer deſcribed in the foregoing ſection is too coſtly and too complicated for being generally uſed in laboratories for meaſuring the gaſes, and is not even applicable to every circumſtance of this kind. In numerous ſeries of experiments, more ſimple and more readily applicable

applicable methods muſt be employed. For this purpoſe I ſhall deſcribe the means I uſed before I was in poſſeſſion of a gazometer, and which I ſtill uſe in preference to it in the ordinary courſe of my experiments.

Suppoſe that, after an experiment, there is a reſiduum of gas, neither abſorbable by alkali nor water, contained in the upper part of the jar AEF, Pl. IV. Fig. 3. ſtanding on the ſhelf of a pneumato-chemical apparatus, of which we wiſh to aſcertain the quantity; we muſt firſt mark the height to which the mercury or water riſes in the jar with great exactneſs, by means of ſlips of paper paſted in ſeveral parts round the jar. If we have been operating in mercury, we begin by diſplacing the mercury from the jar, by introducing water in its ſtead. This is readily done by filling a bottle quite full of water; having ſtopped it with your finger, turn it up, and introduce its mouth below the edge of the jar; then, turning down its body again, the mercury, by its gravity, falls into the bottle, and the water riſes in the jar, and takes the place occupied by the mercury. When this is accompliſhed, pour ſo much water into the ciſtern ABCD as will ſtand about an inch over the ſurface of the mercury; then paſs the diſh BC, Pl. V. Fig. 9. under the jar, and carry it to the water ciſtern, Fig. 1. and 2. We here exchange the gas into another jar, which has been previouſly

previoufly graduated in the manner to be afterwards defcribed; and we thus judge of the quantity or volume of the gas by means of the degrees which it occupies in the graduated jar.

There is another method of determining the volume of gas, which may either be fubftituted in place of the one above defcribed, or may be ufefully employed as a correction or proof of that method. After the air or gas is exchanged from the firft jar, marked with flips of paper, into the graduated jar, turn up the mouth of the marked jar, and fill it with water exactly to the marks EF, Pl. IV. Fig. 3. and by weighing the water, the volume of the air or gas it contained may be determined; allowing one cubical foot or 1728 cubical inches, French meafure, for each 70 *libs*. French weight, or the fame cubical volume in Englifh meafure for each 75.84 *libs*. Englifh Troy, of the water.

The manner of graduating jars for this purpofe is very eafy, and we ought to be provided with feveral of different fizes, and even feveral of each fize, in cafe of accidents. Take a tall, narrow, and ftrong glafs-jar, and having filled it with water in the ciftern, Pl. V. Fig. 1. place it upon the fhelf ABCD; we ought always to ufe the fame place for this operation, that the level of the fhelf may be always exactly fimilar, by which almoft the only error to which this procefs is liable will be avoided. Then take a nar-

row-

row-mouthed phial, holding exactly 5 *oz.* 2 *drams*, 12 *grs.* of water, which correſponds to 10 cubical inches. If you have not one exactly of this dimenſion, chooſe one a little larger, and diminiſh its capacity to the ſize requiſite, by dropping in a little melted wax and roſin. This ſmall phial ſerves the purpoſe of a ſtandard for gaging the jars. Make the air contained in this bottle paſs into the jar, and mark exactly the place to which the water has deſcended; add another meaſure of air, and again mark the place of the water, and ſo on, till all the water be diſplaced. It is of great conſequence that, during the courſe of this operation, the bottle and jar be kept at the ſame temperature with the water in the ciſtern; and, for this reaſon, we muſt refrain as much as poſſible from keeping the hands upon either, or, if we ſuſpect they have been heated, we muſt cool them again by means of the water in the ciſtern. The height of the barometer and thermometer during this experiment is of no conſequence.

When the marks have been thus aſcertained upon the jar for every ten cubical inches, we engrave a ſcale upon one of its ſides by means of a diamond pencil. Glaſs-tubes are graduated in the ſame manner, for uſing in the mercurial apparatus, only they muſt be divided into cubical inches, and tenths of a cubical inch. The bottle uſed for gaging theſe muſt hold 7 *oz.*

1 *dr.*

1 *dr.* 15. *grs.* of mercury, which exactly correspond to a cubical inch of that metal.

This method of determining the volume of air or gas, by means of a graduated jar, has the advantage of not requiring any correction for the difference of height between the surface of the water within the jar, and in the cistern; but it requires corrections with respect to the height of the barometer and thermometer. But, when we ascertain the volume of air by weighing the water which the jar is capable of containing, up to the marks EF, it is necessary to make a farther correction, for the difference between the surface of the water in the cistern, and the height to which it rises within the jar. This will be explained in the fifth section of this Chapter.

SECT. IV.

Of the Method of Separating the different Gases from each other.

As experiments often produce two, three, or more species of gas, it is necessary to be able to separate these from each other, that we may ascertain the quantity and species of each. Sup-

 pose

pose that under the jar A, Pl. IV. Fig. 3. is contained a quantity of different gases mixed together, and standing over mercury; we begin by marking with slips of paper, as before directed, the height at which the mercury stands within the glass; and then introduce about a cubical inch of water into the jar, which will swim over the surface of the mercury: If the mixture of gas contains any muriatic or sulphurous acid gas, a rapid and considerable absorption will instantly take place, from the strong tendency these two gases have, especially the former, to combine with, or be absorbed by water. If the water only produces a slight absorption of gas, hardly equal to its own bulk, we conclude, that the mixture neither contains muriatic acid, sulphuric acid, or ammoniacal gas, but that it contains carbonic acid gas, of which water only absorbs about its own bulk. To ascertain this conjecture, introduce some solution of caustic alkali, and the carbonic acid gas will be gradually absorbed in the course of a few hours; it combines with the caustic alkali or potash, and the remaining gas is left almost perfectly free from any sensible residuum of carbonic acid gas.

After each experiment of this kind, we must carefully mark the height at which the mercury stands within the jar, by slips of paper pasted on, and varnished over when dry, that they may

not

not be waſhed off when placed in the water apparatus. It is likewiſe neceſſary to regiſter the difference between the ſurface of the mercury in the ciſtern and that in the jar, and the height of the barometer and thermometer, at the end of each experiment.

When all the gas or gaſes abſorbable by water and potaſh are abſorbed, water is admitted into the jar to diſplace the mercury: and, as is deſcribed in the preceding ſection, the mercury in the ciſtern is to be covered by one or two inches of water. After this, the jar is to be tranſported by means of the flat diſh BC, Pl. V. Fig. 9. into the water-apparatus; and the quantity of gas remaining is to be aſcertained by changing it into a graduated jar. After this, ſmall trials of it are to be made by experiments in little jars, to aſcertain nearly the nature of the gas in queſtion. For inſtance, into a ſmall jar full of the gas, Fig. 8. Pl. V. a lighted taper is introduced; if the taper is not immediately extinguiſhed, we conclude the gas to contain oxygen gas; and in proportion to the brightneſs of the flame, we may judge if it contain leſs or more oxygen gas than atmoſpheric air contains. If, on the contrary, the taper be inſtantly extinguiſhed, we have ſtrong reaſon to preſume that the reſiduum is chiefly compoſed of azotic gas. If, upon the approach of the taper, the gas takes fire and burns quietly at the

ſurface with a white flame, we conclude it to be pure hydrogen gas; if this flame is blue, we judge it conſiſts of carbonated hydrogen gas; and, if it takes fire with a ſudden deflagration, that it is a mixture of oxygen and hydrogen gas. If, again, upon mixing a portion of the reſiduum with oxygen gas, red fumes are produced, we conclude that it contains nitrous gas.

Theſe preliminary trials give ſome general knowledge of the properties of the gas, and nature of the mixture, but are not ſufficient to determine the proportions and quantities of the ſeveral aſes of which it is compoſed. For this purpoſe all the methods of analyſis muſt be employed; and, to direct theſe properly, it is of great uſe to have a previous approximation by the above methods. Suppoſe, for inſtance, we know that the reſiduum conſiſts of oxygen and azotic gas mixed together, put a determinate quantity, 100 parts, into a graduated tube of ten or twelve lines diameter, introduce a ſolution of ſulphuret of potaſh in contact with the gas, and leave them together for ſome days; the ſulphuret abſorbs the whole oxygen gas, and leaves the azotic gas pure.

If it is known to contain hydrogen gas, a determinate quantity is introduced into Volta's eudiometer, along with a known proportion of oxygen gas; theſe are deflagrated together by means of the electrical ſpark; freſh portions of oxygen

oxygen gas are ſucceſſively added, till no farther deflagration takes place, and till the greateſt poſſible diminution is produced. By this proceſs water is formed, which is immediately abſorbed by the water of the apparatus; but, if the hydrogen gas contain carbon, carbonic acid is formed at the ſame time, which is not abſorbed ſo quickly; the quantity of this is readily aſcertained by aſſiſting its abſorption, by means of agitation. If the reſiduum contains nitrous gas, by adding oxygen gas, with which it combines into nitric acid, we can very nearly aſcertain its quantity, from the diminution produced by this mixture.

I confine myſelf to theſe general examples, which are ſufficient to give an idea of this kind of operations; a whole volume would not ſerve to explain every poſſible caſe. It is neceſſary to become familiar with the analyſis of gaſes by long experience; we muſt even acknowledge that they moſtly poſſeſs ſuch powerful affinities to each other, that we are not always certain of having ſeparated them completely. In thoſe caſes, we muſt vary our experiments in every poſſible point of view; adding new agents to the combination, and keeping out others, and muſt continue our trials, till we are certain of the truth and exactitude of our concluſions.

SECT. V.

Of the neceſſary Corrections upon the Volume of the Gaſes, according to the Preſſure of the Atmoſphere.

All elaſtic fluids are compreſſible or condenſible, in proportion to the weight with which they are loaded. Perhaps this law, which is aſcertained by general experience, may ſuffer ſome irregularity when theſe fluids are under a degree of condenſation almoſt ſufficient to reduce them to the liquid ſtate, or when either in a ſtate of extreme rarefaction or condenſation; but we ſeldom approach either of theſe limits with moſt of the gaſes which we ſubmit to our experiments. I underſtand this propoſition of gaſes being compreſſible, in proportion to their ſuperincumbent weights, as follows:

A barometer, which is an inſtrument generally known, is, properly ſpeaking, a ſpecies of ſyphon, ABCD, Pl. XII. Fig. 16. whoſe leg AB is filled with mercury, while the leg CD is full of air. If we ſuppoſe the branch CD indefinitely continued till it equals the height of our atmoſphere, we can readily conceive that the barometer is, in reality, a ſort of balance, in which a

a column of mercury ſtands in equilibrium with a column of air of the ſame weight. But it is unneceſſary to prolongate the branch CD to ſuch a height, as it is evident that the barometer being immerſed in air, the column of mercury AB will be equally in equilibrium with a column of air of the ſame diameter, though the leg CD be cut off at C, and the part CD be taken away altogether.

The medium height of mercury in equilibrium wtth the weight of a column of air, from the higheſt part of the atmoſphere to the ſurface of the earth, is about twenty-eight French or 29.85 Engliſh inches in the lower parts of the city of Paris; or, in other words, the air at the ſurface of the earth at Paris is uſually preſſed upon by a weight equal to that of a column of mercury twenty-eight inches in height. I muſt be underſtood in this way, in the ſeveral parts of this publication, when talking of the different gaſes; as, for inſtance, when the cubical foot of oxygen gas is ſaid to weigh 538.45 *grs.* under 29.85 inches preſſure. The height of this column of mercury, ſupported by the preſſure of the air, diminiſhes in proportion as we are elevated above the ſurface of the earth, or rather above the level of the ſea; becauſe the mercury can only form an equilibrium with the column of air which is above it, and is not in the ſmalleſt degree affected by the air which is below its level.

In what ratio does the mercury in the barometer deſcend in proportion to its elevation? or, which is the ſame thing, according to what law or ratio do the ſeveral ſtrata of the atmoſphere decreaſe in denſity? This queſtion, which has exerciſed the ingenuity of natural philoſophers during the laſt century, is conſiderably elucidated by the following experiment.

If we take the glaſs ſyphon ABCDE, Pl. XII, Fig. 17. ſhut at E, and open at A, and introduce a f w drops of mercury, ſo as to intercept the communication of air between the leg AB and the leg BE, it is evident that the air contained in BCDE is preſſed upon, in common with the whole ſurrounding air, by a weight or column of air equal to 29.85 inches of mercury. But, if we pour 29.85 inches of mercury into the leg AB, it is plain that the air in the branch BCDE will then be preſſed upon by a weight equal to twice 29.85 inches of mercury, or twice the weight of the atmoſphere; and experience ſhews that, in this caſe, the included air, inſtead of filling the tub from B to E, only occupies from C to E, or exactly one-half of the ſpace it filled before. If to this firſt column of mercury we add two other portions of 29.85 inches each, in the branch AB, the air in the branch BCDE will be preſſed upon by four times the weight of the atmoſphere, or four times the weight of 29.85 inches of mercury, and it will then only fill the ſpace

ſpace from D to E, or exactly one-quarter of the ſpace it occupied at the commencement of the experiment. From theſe experiments, which may be infinitely varied, it has been deduced as a general law of nature, which ſeems applicable to all permanently elaſtic fluids, that they diminiſh in volume directly in proportion to the weight with which they are preſſed; or, in other words, "*the volume of all elaſtic fluids is in the* "*inverſe ratio of the weight by which they are* "*compreſſed.*"

The experiments which have been made for meaſuring the heights of mountains by means of the barometer, confirm the truth of theſe deductions; and, even ſuppoſing them in ſome degree inaccurate, theſe differences are ſo extremely ſmall, that they may be reckoned as nothing in chemical experiments. When this law of the compreſſion of elaſtic fluids is once well underſtood, it becomes eaſily applicable to the corrections, neceſſary in pneumato-chemical experiments, upon the volume of gas, in relation to its preſſure. Theſe corrections are of two kinds, the one relative to the variations of the barometer, and the other for the column of water or mercury contained in the jars. I ſhall endeavour to explain theſe by examples, beginning with the moſt ſimple caſe.

Suppoſe that 100 cubical inches of oxygen gas are obtained at 54.5° of the thermometer, and

and at 30.37 inches of the barometer, it is required to know what volume the 100 cubical inches of gas would occupy, under the preſſure of 29.85 inches, and what is the exact weight of the 100 inches of oxygen gas? Let the unknown volume, or the number of inches this gas would occupy at 29.85 inches of the barometer, be expreſſed by *x*; and, ſince the volumes are in the inverſe ratio of their ſuperincumbent weights, we have the following ſtatement: 100 cubical inches is to *x*, inverſely as 30.37 inches of preſſure is to 29.85 inches; or directly 29.85 : 30.37 : : 100 : *x* = 101.741 — cubical inches, at 29.85 inches barometrical preſſure; that is to ſay, the ſame gas or air which at 30.37 inches of the barometer occupies 100 cubical inches of volume, will occupy 101.741 cubical inches when the barometer is at 29.85 inches. It is equally eaſy to calculate the weight of this gas, occupying 100 cubical inches, under 30.37 inches of barometrical preſſure; for, as it correſponds to 101.741 cubical inches at the preſſure of 29.85; and as, at this preſſure, and at 54.5° of temperature, each cubical inch of oxygen gas weighs 0.311023 *gr.* it follows, that 100 cubical inches, under 30.37 barometrical preſſure, muſt weigh 31.644 grains. This concluſion might have been formed more directly; as, ſince the volume of elaſtic fluids is in the inverſe ratio of their compreſſion, their weights muſt

muſt be in the direct ratio of the ſame compreſſion: Hence, ſince 100 cubical inches weigh 31.1023 grains, under the preſſure of 29.85 inches, we have the following ſtatement to determine the weight of 100 cubical inches of the ſame gas at 30.37 barometrical preſſure; 29.85: 31.1023 : : 30.37 : x, the unknown quantity, = 31.644.

The following caſe is more complicated: Suppoſe the jar A, Pl. XII. Fig. 18. to contain a quantity of gas in its upper part ACD, the reſt of the jar below CD being full of mercury, and the whole ſtanding in the mercurial baſon or reſervoir GHIK, filled with mercury up to EF, and that the difference between the ſurface CD of the mercury in the jar, and EF, that in the ciſtern, is ſix inches, while the barometer ſtands at 27.5 inches: It is evident from theſe data, that the air contained in ACD is preſſed upon by the weight of the atmoſphere, diminiſhed by the weight of the column of mercury CE, or by 27.5—6=21.5 inches of barometrical preſſure. This air is therefore leſs compreſſed than the atmoſphere at the mean height of the barometer, and conſequently occupies more ſpace than it would occupy at the mean preſſure, the difference being exactly proportional to the difference between the compreſſing weights. If, then, upon meaſuring the ſpace ACD, it is found to be 120 cubical inches, it muſt be reduced

duced to the volume which it would occupy under the mean preſſure of 29.85 inches. This is done by the following ſtatement : 120 : x, the unknown volume, : : 21.5 : 29.85 inverſely ; this gives $x = \frac{120 \times 21.5}{29.85} = 86.432$ cubical inches.

In theſe calculations we may either reduce the height of the mercury in the barometer, and the difference of level in the jar and baſon, to lines, or to decimal fractions of the inch ; but I prefer the latter, as it is more readily calculated. As, in theſe operations, which frequently recur, it is of great uſe to have means of abbreviation, I have given a table in the appendix for reducing lines and fractions of lines into decimal fractions of the inch.

In experiments performed in the water apparatus, we muſt make ſimilar corrections to procure rigorouſly exact reſults, by taking into account, and making allowance for the difference of height of the water within the jar above the ſurface of the water in the ciſtern. But, as the preſſure of the atmoſphere is expreſſed in inches and lines of the mercurial barometer, and, as homogeneous quantities only can be calculated together, we muſt reduce the obſerved inches and lines of water into correſpondent heights of the mercury. I have given a table in the appendix for this converſion, upon the ſuppoſition that mercury is 13.5681 times heavier than water.

SECT.

SECT. VI.

Of Corrections relative to the Degrees of the Thermometer.

In ascertaining the weight of gases, besides reducing them to a mean of a barometrical pressure, as directed in the preceding section, we must likewise reduce them to a standard thermometrical temperature; because, all elastic fluids being expanded by heat, and condensed by cold, their weight in any determinate volume is thereby liable to considerable alterations. As the temperature of 54.5° is a medium between the heat of summer and the cold of winter, being the temperature of subterraneous places, and that which is most easily approached to at all seasons, I have chosen that degree as a mean to which I reduce air or gas in this species of calculation.

Mr de Luc found, that atmospheric air was increased $\frac{1}{215}$ part of its bulk, by each degree of a mercurial thermometer, divided into 81 degrees, between the freezing and boiling points; this gives $\frac{1}{211}$ part for each degree of Reaumurs

Reaumurs thermometer, which is divided into 80 degrees between theſe two points; or $\frac{1}{474.75}$ part for each degree of Fahrenheits ſcale, which is divided into 180 degrees between the ſame fixed points. The experiments of Mr Monge ſeem to make this dilatation leſs for hydrogen gas, which he thinks is only dilated $\frac{1}{180}$ for each degree of Reaumur, or $\frac{1}{405}$ for each of Fahrenheits degrees. We have not any exact experiments hitherto publiſhed reſpecting the ratio of dilatation of the other gaſes; but, from the trials which have been made, their dilatation ſeems to differ little from that of atmoſpheric air. Hence I may take it for granted, till farther experiments give us better information upon this ſubject, that atmoſpherical air is dilated $\frac{1}{210}$ part, and hydrogen gas $\frac{1}{190}$ part for each degree of Reaumurs thermometer, or that atmoſpheric air is dilated $\frac{1}{472.5}$ part, and hydrogen gas $\frac{1}{47.25}$ part for each degree on the ſcale of Fahrenheit; but, as there is ſtill great uncertainty upon this point, we ought always to operate in a temperature as near as poſſible to the ſtandard of 54.5°; by this means any errors in correcting the weight or volume of gaſes by reducing them to the common ſtandard, will become of little moment.

The calculation for this correction is extremely eaſy. Divide the obſerved volume of air

air by 210, for Reaumurs ſcale, or 472.5 for that of Fahrenheit, and multiply the quotient by the degree of temperature above or below 54.5°. This correction is negative when the actual temperature is above the ſtandard, and poſitive when below. By the uſe of logarithmetical tables, this calculation is much facilitated.

SECT. VII.

Example for calculating the Corrections relative to the variations of Preſſure and Temperature.

CASE.

In the jar A, Pl. IV. Fig. 3. ſtanding in a water-apparatus, is contained 353 cubical inches of air; the ſurface of the water within the jar at EF is $4\frac{1}{2}$ inches above the water in the ciſtern, the barometer is at 27 inches $9\frac{1}{2}$ lines, and the thermometer at 65.75°. Having burnt a quantity of phoſphorus in the air, by which concrete phoſphoric acid is produced, the air after the combuſtion occupies 295 cubical inches, the water within the jar ſtands 7 inches above that in the

the ciſtern, the barometer is at 27 inches $9\frac{1}{2}$ lines, and the thermometer at 68°. It is required from theſe data to determine the actual volume of air, before and after combuſtion, and the quantity abſorbed during the proceſs.

Calculation before Combuſtion.

The air in the jar before combuſtion was 353 cubical inches, but it was only under a barometrical preſſure of 27 inches $9\frac{1}{2}$ lines; which, reduced to decimal fractions by Tab. I. of the Appendix, gives 27.79167 inches; and from this we muſt deduct the difference of $4\frac{1}{2}$ inches of water, which, by Tab. II. correſponds to 0.33166 inches of the barometer; hence the real preſſure of the air in the jar is 27.46001. As the volume of elaſtic fluids diminiſhes in the inverſe ratio of the compreſſing weights, we have the following ſtatement, to reduce the 353 inches to the volume the air would occupy at 28 inches barometrical preſſure.

353 : x, the unknown volume, : : 27.46001 : 28. Hence, $x = \frac{353 \times 27.46001}{28} = 346.192$ cubical inches, which is the volume the ſame quantity of

of air would have occupied at 28 inches of the barometer.

The 472.5th part of this corrected volume is .73247, which, for the 11.25 degrees of temperature above the ſtandard, gives 8.24 cubical inches; and, as this correction is ſubtractive, the real corrected volume of the air before combuſtion is 337.952 inches.

Calculation after Combuſtion.

By a ſimilar calculation upon the volume of air after combuſtion, we find its barometrical preſſure 27.77083 — 0.51593 = 27.25490. Hence, to have the volume of air under the preſſure of 28 inches, 295 : x : : 27 77083 : 28 inverſely; or $x = \frac{295 \times 27.25490}{28} = 287.150$. The 472.5th part of this corrected volume, is .61, which, multiplied by 13.5 degrees of thermometrical difference, gives the ſubtractive correction for temperature, 8.235, leaving the actual corrected volume of air after combuſtion 278.915 inches.

Result.

The corrected volume before combustion, - - -	337.952
Ditto, remaining after combustion, - -	278.915
Volume absorbed during combustion,	59.037

SECT. VIII.

Method of determining the Absolute Gravity of the different Gases.

Take a large balloon A, Pl. V. Fig. 10. capable of holding 17 or 18 pints, or about half a cubical foot, having the brass cap *bcde* strongly cemented to its neck, and to which the tube and stop-cock *f g* is fixed by a tight screw. This apparatus is connected by the double screw represented separately at Fig. 12. to the jar BCD Fig. 10., which must be some pints larger in dimensions than the balloon. This jar is open at top, and is furnished with the brass cap *h i*, and the stop-cock *l m*. One of these stop-cocks is represented separately at Fig. 11.

We

We firſt determine the exact capacity of the balloon by filling it with water, and weighing it both full and empty. When emptied of water, it is dried with a cloth introduced through its neck *d e*, and the laſt remains of moiſture are removed by exhauſting it once or twice in an air-pump.

When the weight of any gas is to be aſcertained, this apparatus is uſed as follows: Fix the balloon A to the plate of an air-pump, by means of the ſcrew of the ſtop-cock *f g*, which is left open; the balloon is to be exhauſted as completely as poſſible, obſerving carefully the degree of exhauſtion by means of the barometer attached to the air-pump. When the vacuum is formed, the ſtop-cock *f g* is ſhut, and the weight of the balloon determined with the moſt ſcrupulous exactitude. It is then fixed to the jar BCD, which we ſuppoſe placed in water in the ſhelf of the pneumato-chemical apparatus Fig. 1.; the jar is to be filled with the gas we mean to weigh, and then, by opening the ſtop-cocks *f g* and *l m*, the gas aſcends into the balloon, whilſt the water of the ciſtern riſes at the ſame time into the jar. To avoid very troubleſome corrections, it is neceſſary, during this firſt part of the operation, to ſink the jar in the ciſtern till the ſurfaces of the water within and without the jar exactly correſpond. The ſtop-cocks are again ſhut, and the balloon, being un-

 ſcrewed

ſcrewed from its connection with the jar, is to be carefully weighed; the difference between this weight and that of the exhauſted balloon is the preciſe weight of the air or gas contained in the balloon. Multiply this weight by 1728, the number of cubical inches in a cubical foot, and divide the product by the number of cubical inches contained in the balloon, the quotient is the weight of a cubical foot of the gas or air ſubmitted to experiment.

Exact account muſt be kept of the barometrical height and the temperature of the thermometer during the above experiment; and from theſe the reſulting weight of a cubical foot is eaſily corrected to the ſtandards of 28 inches preſſure, and 54.5° temperature, as directed in the preceding ſection. The ſmall portion of air remaining in the balloon after forming the vacuum, muſt likewiſe be attended to, and this is eaſily determined by the barometer attached to the air-pump. If that barometer, for inſtance, remains at the hundredth part of the height it ſtood at before the vacuum was formed, we conclude that one hundredth part of the air originally contained remains in the balloon, and conſequently that only $\frac{99}{100}$ of gas was introduced from the jar into the balloon.

CHAP. III.

Description of the Calorimeter, or Apparatus for measuring Caloric.

THE calorimeter, or apparatus for meaſuring the relative quantities of heat contained in bodies, was deſcribed by Mr de la Place and me in the Memoirs of the Academy for 1780, p. 355. and from that Eſſay the materials of this chapter are extracted.

If, after having cooled any body to the freezing point, it be expoſed in an atmoſphere of 88.25°, the body will gradually become heated, from the ſurface inwards, till at laſt it acquire the ſame temperature with the ſurrounding air. But, if a piece of ice be placed in the ſame ſituation, the circumſtances are quite different; it does not approach in the ſmalleſt degree towards the temperature of the circumambient air, but remains conſtantly at 32°, or the temperature of melting ice, till the laſt portion of ice be completely melted.

This phenomenon is readily explained; as, to melt ice, or reduce it to water, it requires to be combined with a certain portion of caloric,

 the

the whole caloric attracted from the surrounding bodies, is arrested or fixed at the surface or external layer of ice which it is employed to dissolve, and combines with it to form water; the next quantity of caloric combines with the second layer to dissolve it into water, and so on successively till the whole ice be dissolved, or converted into water, by combination with caloric; the very last atom still remaining at its former temperature, because the caloric could never penetrate so far, while any intermediate ice remained to melt, or to combine with.

Upon these principles, if we conceive a hollow sphere of ice at the temperature of 32° placed in an atmosphere of 54.5°, and containing a substance at any degree of temperature above freezing; it follows, That the heat of the external atmosphere cannot penetrate into the internal hollow of the sphere of ice; and, That the heat of the body which is placed in the hollow of the sphere cannot penetrate outwards beyond it, but will be stopped at the internal surface, being continually employed to melt successive layers of ice, until the temperature of the body be reduced to 32°, by having all its superabundant caloric above that temperature carried off to melt the ice. If the whole water, formed within the sphere of ice during the reduction of the temperature of the included body to 32°, be carefully collected, the weight of

of the water will be exactly proportional to the quantity of caloric loſt by the body, in paſſing from its original temperature to that of melting ice; for it is evident that a double quantity of caloric would have melted twice the quantity of ice. Hence the quantity of ice melted is a very exact meaſure of the proportional quantity of caloric employed to produce that effect, and conſequently of the quantity loſt by the only ſubſtance that could poſſibly have ſupplied it.

I have made this ſuppoſition, of what would take place in a hollow ſphere of ice, for the purpoſe of more readily explaining the method uſed in this ſpecies of experiment, which was firſt conceived by Mr de la Place. It would be difficult to procure ſuch ſpheres of ice, and inconvenient to make uſe of them when got; but, by means of the following apparatus, we have remedied that defect. I acknowledge the name of Calorimeter, which I have given it, as derived partly from Greek and partly from Latin, is in ſome degree open to criticiſm; but, in matters of ſcience, a ſlight deviation from ſtrict etymology, for the ſake of giving diſtinctneſs of idea, is excuſable; and I could not derive the name entirely from Greek without approaching too near to the names of known inſtruments employed for other purpoſes.

The calorimeter is repreſented in Pl. VI. It is ſhown in perſpective at Fig. 1. and its interior

 ſtructure

ſtructure is engraved at Fig. 2. and 3.; the former being a horizontal, and the latter a perpendicular ſection. Its capacity or cavity is divided into three parts, which, for better diſtinction, I ſhall name the interior, middle, and external cavities. The interior cavity *ffff*, Fig. 4. into which the ſubſtances ſubmitted to experiment are put, is compoſed of a grating or cage of iron-wire, ſupported by ſeveral iron-bars; its opening or mouth LM, is covered by the lid HG, which is compoſed of the ſame materials. The middle cavity *b b b b*, Fig. 2. and 3. is intended to contain the ice which ſurrounds the interior cavity, and which is intended to be melted by the caloric of the ſubſtances employed in the experiment. The ice is ſupported by the grate *m m* at the bottom of the cavity, under which is placed the ſieve *n n*. Theſe two are repreſented ſeparately in Fig. 5. and 6.

In proportion as the ice contained in the middle cavity is melted, by the caloric diſengaged from the body placed in the interior cavity, the water runs through the grate and ſieve, and falls through the conical funnel *c c d*, Fig. 3. and the tube *x y*, into the receiver F, Fig. 1. This water may be retained or let out at pleaſure, by means of the ſtop-cock *u*. The external cavity *a a a a*, Fig. 2. and 3. is filled with ice, to prevent any effect upon the ice in the middle cavity

vity from the heat of the surrounding air, and the water produced from it is carried off through the pipe ST, which shuts by means of the stop-cock *r*. The whole machine is covered by the lid FF, Fig. 7. which is made of tin, and painted with oil colour, to prevent rust.

When this machine is employed, the middle cavity *b b b b*, Fig. 2. and 3. the lid GH, Fig. 4. of the interior cavity, the external cavity *a a a a*, Fig. 2. and 3. and the general lid FF, Fig. 7. are all filled with pounded ice, well rammed, so that no void spaces remain, and the ice of the middle cavity is allowed to drain. The machine is then opened, and the substance submitted to experiment being placed in the interior cavity, it is instantly closed. After waiting till the included body is completely cooled to the freezing point, and the whole melted ice has drained from the middle cavity, the water collected in the vessel F, Fig. 1. is accurately weighed. The weight of the water produced during the experiment is an exact measure of the caloric disengaged during the cooling of the included body, as this substance is evidently in a similar situation with the one formerly mentioned as included in a hollow sphere of ice. The whole caloric disengaged from the included body is stopped by the ice in the middle cavity, and that ice is preserved from being affected by any other heat by means of the ice contained in the general

ral lid, Fig. 7. and in the external cavity. Experiments of this kind generally laſt from fifteen to twenty hours, but they are ſometimes accelerated by covering up the ſubſtance in the interior cavity with well-drained ice, which haſtens its cooling.

The ſubſtances to be operated upon are placed in the thin iron-bucket, Fig. 8. the cover of which has an opening fitted with a cork, into which a ſmall thermometer is fixed. When we uſe acids, or other fluids capable of injuring the metal of the inſtruments, they are contained in the matraſs, Fig. 9. which has a ſimilar thermometer in a cork fitted to its mouth, and which ſtands in the interior cavity upon the ſmall cylindrical ſupport RS, Fig. 10.

It is abſolutely requiſite that there be no communication between the external and middle cavities of the calorimeter, otherwiſe the ice melted by the influence of the ſurrounding air, in the external cavity, would mix with the water produced from the ice of the middle cavity, which would no longer be a meaſure of the caloric loſt by the ſubſtance ſubmitted to experiment.

When the temperature of the atmoſphere is only a few degrees above the freezing point, its heat can hardly reach the middle cavity, being arreſted by the ice of the cover, Fig. 7. and of the external cavity; but if the temperature of the

the air be under the degree of freezing, it might cool the ice contained in the middle cavity, by cauſing the ice in the external cavity to fall, in the firſt place, below 32°. It is therefore eſſential that this experiment be carried on in a temperature ſomewhat above freezing: Hence, in time of froſt, the calorimeter muſt be kept in an apartment carefully heated. It is likewiſe neceſſary that the ice employed be not under 32°, for which purpoſe it muſt be pounded, and ſpread out thin for ſome time, in a place where the temperature is higher.

The ice of the interior cavity always retains a certain quantity of water adhering to its ſurface, which may be ſuppoſed to belong to the reſult of the experiment; but as, at the beginning of each experiment, the ice is already ſaturated with as much water as it can contain, if any of the water produced by the caloric ſhould remain attached to the ice, it is evident, that very nearly an equal quantity of what adhered to it before the experiment muſt have run down into the veſſel F in its ſtead; for the inner ſurface of the ice in the middle cavity is very little changed during the experiment.

By any contrivance that could be deviſed, we could not prevent the acceſs of the external air into the interior cavity, when the atmoſphere was at 52° or 54°. The air confined in the cavity being in that caſe ſpecifically heavier than the

the external air, efcapes downwards through the pipe *x y*, Fig. 3. and is replaced by the warmer external air, which, giving out its caloric to the ice, becomes heavier, and finks in its turn; thus, a current of air is formed through the machine, which is the more rapid in proportion as the external air exceeds the internal in temperature. This current of warm air muft melt a part of the ice, and injure the accuracy of the experiment. We may, in a great degree, guard againft this fource of error, by keeping the ftop-cock *u* continually fhut, but it is better to operate only when the temperature of the external air does not exceed 39°, or at moft 41°, for we have obferved, that, in this cafe, the melting of the interior ice by the atmofpheric air is perfectly infenfible; fo that we may anfwer for the accuracy of our experiments upon the fpecific heat of bodies to a fortieth part.

We have had two of thefe machines made; one, which is intended for fuch experiments as do not require the interior air to be renewed, is formed precifely according to the defcription here given; the other, which anfwers for experiments upon combuftion, refpiration, &c. in which frefh quantities of air are indifpenfably neceffary, differs from the former in having two fmall tubes in the two lids, by which a current of atmofpheric air may be blown into the interior cavity of the machine.

It

It is extremely easy, with this apparatus, to determine the phenomena which occur in operations where caloric is either disengaged or absorbed. If we wish, for instance, to ascertain the quantity of caloric which is disengaged from a solid body in cooling a certain number of degrees; let its temperature be first raised to 212°, it is then placed in the interior cavity *ffff*, Fig. 2. and 3. of the calorimeter, and allowed to remain till we are certain that its temperature is reduced to 32°; the water produced by melting the ice during its cooling is collected, and carefully weighed; and this weight, divided by the volume of the body submitted to experiment, and multiplied into the degrees of temperature which it had above 32° at the commencement of the experiment, gives the proportion of what the English philosophers call specific heat.

Fluids are contained in proper vessels, whose specific heat has been previously ascertained, and are operated upon in the machine in the same manner as directed for solids, taking care to deduct, from the quantity of water melted during the experiment, the proportion which belongs to the specific heat of the containing vessel.

If the quantity of caloric disengaged during the combination of different substances, is to be determined, these substances are to be previously reduced to the freezing degree by keeping them

them a ſufficient time ſurrounded with pounded ice; the mixture is then to be made in the inner cavity of the calorimeter, in a proper veſſel likewiſe reduced to 32°; and they are kept incloſed till the temperature of the combination has returned to the ſame degree: The quantity of water produced is a meaſure of the caloric diſengaged during the combination.

To determine the quantity of caloric diſengaged during combuſtion, and during animal reſpiration, the combuſtible bodies are burnt, or the animals are made to breathe, in the interior cavity, and the water produced is carefully collected. Guinea-pigs, which reſiſt the effects of cold extremely well, are well adapted for this experiment. As the continual renewal of air is abſolutely neceſſary in ſuch experiments, we blow freſh air into the interior cavity of the calorimeter by means of a pipe deſtined for that purpoſe, and allow it to eſcape through another pipe of the ſame kind; and that the heat of this air may not produce errors in the reſults of the experiments, the tube which conveys it into the machine is made to paſs through pounded ice, that it may be reduced to 32° before it arrives at the calorimeter. The air which eſcapes muſt likewiſe be made to paſs through a tube ſurrounded with ice, included in the interior cavity of the machine, and the water which is there produced muſt make a part of what is collected,

because

because the caloric disengaged from this air is part of the product of the experiment.

It is somewhat more difficult to determine the specific caloric contained in the different gases, on account of their small degree of density; for, if they are only placed in the calorimeter in vessels like other fluids, the quantity of ice melted is so small, that the result of the experiment becomes at best very uncertain. For this species of experiment we have contrived to make the air pass through two metallic worms, or spiral tubes; one of these, through which the air passes, and becomes heated in its way to the calorimeter, is contained in a vessel full of boiling water, and the other, through which the air circulates within the calorimeter to disengage its caloric, is placed in the interior cavity, *ffff*, of that machine. By means of a small thermometer placed at one end of the second worm, the temperature of the air, as it enters the calorimeter, is determined, and its temperature in getting out of the interior cavity is found by another thermometer placed at the other end of the worm. By this contrivance we are enabled to ascertain the quantity of ice melted by determinate quantities of air or gas, while losing a certain number of degrees of temperature, and, consequently, to determine their several degrees of specific caloric. The same apparatus, with some particular precautions, may be employed

to

to aſcertain the quantity of caloric diſengaged by the condenſation of the vapours of different liquids.

The various experiments which may be made with the calorimeter do not afford abſolute concluſions, but only give us the meaſure of relative quantities; we have therefore to fix a unit, or ſtandard point, from whence to form a ſcale of the ſeveral reſults. The quantity of caloric neceſſary to melt a pound of ice has been choſen as this unit; and, as it requires a pound of water of the temperature of 167° to melt a pound of ice, the quantity of caloric expreſſed by our unit or ſtandard point, is what raiſes a pound of water from 32° to 167°. When this unit is once determined, we have only to expreſs the quantities of caloric diſengaged from different bodies, by cooling a certain number of degrees, in analogous values: The following is an eaſy mode of calculation for this purpoſe, applied to one of our earlieſt experiments.

We took 7 *lib.* 11 *oz.* 2 *gros* 36 *grs.* of plate-iron, cut into narrow ſlips, and rolled up, or expreſſing the quantity in decimals, 7.7070319 *libs.* Theſe being heated in a bath of boiling water to about 207.5°, were quickly introduced into the interior cavity of the calorimeter: At the end of eleven hours, when the whole quantity of water melted from the ice had thoroughly drained off, we found that 1.109795 pounds

pounds of ice were melted. Hence, the caloric disengaged from the iron by cooling 175.5° having melted 1.109795 pounds of ice, How much would have been melted by cooling 135° ? This question gives the following statement in direct proportion, 175.5 : 1.109795 : : 135 : x=0.85384. Dividing this quantity by the weight of the whole iron employed, viz. 7.7070319, the quotient 0.1109 is the quantity of ice which would have been melted by one pound of iron while cooling through 135 degrees of temperature.

Fluid substances, such as sulphuric and nitric acids, &c. are contained in a matrass, Pl. VI. Fig. 9. having a thermometer adapted to the cork, with its bulb immersed in the liquid. The matrass is placed in a bath of boiling water, and when, from the thermometer, we judge the liquid is raised to a proper temperature, the matrass is placed in the calorimeter. The calculation of the products, to determine the specific caloric of these fluids, is made as above directed, taking care to deduct from the water obtained the quantity which would have been produced by the matrass alone, which must be ascertained by a previous experiment. The table of the results obtained by these experiments is omitted, because not yet sufficiently complete, different circumstances having occasioned the series to be interrupted : it is not, however, lost sight of ; and we are less or more employed upon the subject every winter.

CHAP. IV.

Of Mechanical Operations for the Divifion of Bodies.

SECT. I.

Of Trituration, Levigation, and Pulverization.

THESE are, properly fpeaking, only preliminary mechanical operations for dividing and feparating the particles of bodies, and reducing them into very fine powder. Thefe operations can never reduce fubftances into their primary, or elementary and ultimate particles; they do not even deftroy the aggregation of bodies; for every particle, after the moft accurate trituration, forms a fmall whole, refembling the original mafs from which it was divided. The real chemical operations, on the contrary, fuch as folution, deftroy the aggregation of bodies, and feparate their conftituent and integrant particles from each other.

Brittle

Brittle ſubſtances are reduced to powder by means of peſtles and mortars. Theſe are of braſs or iron, Pl. I. Fig. 1.; of marble or granite, Fig. 2.; of lignum vitæ, Fig. 3.; of glaſs, Fig. 4.; of agate, Fig. 5.; or of porcelain, Fig. 6. The peſtles for each of theſe are repreſented in the plate, immediately below the mortars to which they reſpectively belong, and are made of hammered iron or braſs, of wood, glaſs, porcelain, marble, granite, or agate, according to the nature of the ſubſtances they are intended to triturate. In every laboratory, it is requiſite to have an aſſortment of theſe utenſils, of various ſizes and kinds: Thoſe of porcelain and glaſs can only be uſed for rubbing ſubſtances to powder, by a dexterous uſe of the peſtle round the ſides of the mortar, as it would be eaſily broken by reiterated blows of the peſtle.

The bottom of mortars ought to be made in form of a hollow ſphere, and their ſides ſhould have ſuch a degree of inclination as to make the ſubſtances they contain fall back to the bottom when the peſtle is lifted, but not ſo perpendicular as to collect them too much together, otherwiſe too large a quantity would get below the peſtle, and prevent its operation. For this reaſon, likewiſe, too large a quantity of the ſubſtance to be powdered ought not to be put into the mortar at one time; and we muſt from

time to time get rid of the particles already reduced to powder, by means of ſieves to be afterwards deſcribed.

The moſt uſual method of levigation is by means of a flat table ABCD, Pl. I. Fig. 7. made of porphyry, or ſome other ſtone of ſimilar hardneſs; on this the ſubſtance to be reduced to powder is ſpread, and is then bruiſed and rubbed by a muller M, of the ſame hard materials, the bottom of which is made a ſmall portion of a large ſphere; and, as the muller tends continually to drive the ſubſtances towards the ſides of the table, a thin flexible knife, or ſpatula of iron, horn, wood, or ivory, is uſed for bringing them back to the middle of the ſtone.

In large works, this operation is performed by means of large rollers of hard ſtone, which turn upon each other, either horizontally, in the way of corn-mills, or by one vertical roller turning upon a flat-ſtone. In the above operations, it is often requiſite to moiſten the ſubſtances a little, to prevent the fine powder from flying off.

There are many bodies which cannot be reduced to powder by any of the foregoing methods; ſuch are fibrous ſubſtances, as woods, ſuch ſubſtances as are tough and elaſtic, as the horns of animals, elaſtic gum, &c. and the malleable metals, which flatten under the peſtle, inſtead of being reduced to powder. For redu-

cing

cing the woods to powder, rafps, as in Pl. I. Fig. 8. are employed; files of a finer kind are ufed for horn; and ftill finer, Pl. I. Fig. 9. and 10. for metals.

Some of the metals, though not brittle enough to powder under the peftle, are too foft to be filed, as they clog the file, and prevent its operation. Zinc is one of thefe, but it may be powdered when hot, in a heated iron mortar, or it may be rendered brittle, by alloying it with a fmall quantity of mercury. One or other of thefe methods is ufed by fire-work makers for producing a blue flame by means of zinc. Metals may be reduced into grains, by pouring them when melted into water, which method ferves very well when they are not wanted in fine powder.

Fruits, potatoes, &c. of a pulpy and fibrous nature, may be reduced to pulp by means of the grater, Pl. I. Fig. 11.

The choice of the different fubftances of which thefe inftruments are made is a matter of importance; brafs or copper are unfit for operations upon fubftances to be ufed as food or in pharmacy; and marble or metallic inftruments muft not be ufed for acid fubftances; hence mortars of very hard wood, and thofe of porcelain, granite, or glafs, are of great utility in many operations.

SECT. II.

Of Sifting and Washing Powdered Subſtances.

None of the mechanical operations, employed for reducing bodies to powder, is capable of producing it of an equal degree of fineneſs throughout; the powder obtained by the longeſt and moſt accurate trituration being ſtill an aſſemblage of particles of various ſizes. The coarſer of theſe are removed, ſo as only to leave the finer and more homogeneous particles, by means of ſieves, Pl. I. Fig. 12, 13, 14, 15. of different fineneſſes, adapted to the particular purpoſes they are intended for; all the powdered matter which is larger than the interſtices of the ſieve remains behind, and is again ſubmitted to the peſtle, while the finer paſſes through. The ſieve Fig. 12. is made of hair-cloth or of ſilk-gauze; and the one repreſented Fig. 13. is of parchment pierced with round holes of a proper ſize; this latter is employed in the manufacture of gun-powder. When very ſubtile or valuable materials are to be ſifted, which are eaſily diſperſed, or when the finer parts of the powder may be hurtful, a compound ſieve, Fig. 15. is made uſe of, which conſiſts of the ſieve ABCD, with

with a lid EF, and receiver GH; theſe three parts are repreſented as joined together for uſe, Fig. 14.

There is a method of procuring powders of an uniform fineneſs, conſiderably more accurate than the ſieve; but it can only be uſed with ſuch ſubſtances as are not acted upon by water. The powdered ſubſtance is mixed and agitated with water, or any other convenient fluid; the liquor is allowed to ſettle for a few moments, and is then decanted off; the coarſer powder remains at the bottom of the veſſel, and the finer paſſes over with the liquid. By repeated decantations in this manner, various ſediments are obtained of different degrees of fineneſs; the laſt ſediment, or that which remains longeſt ſuſpended in the liquor, being the fineſt. This proceſs may likewiſe be uſed with advantage for ſeparating ſubſtances of different degrees of ſpecific gravity, though of the ſame fineneſs; this laſt is chiefly employed in mining, for ſeparating the heavier metallic ores from the lighter earthy matters with which they are mixed.

In chemical laboratories, pans and jugs of glaſs or earthen ware, are employed for this operation; ſometimes for decanting the liquor without diſturbing the ſediment, the glaſs ſyphon ABCHI, Pl. II. Fig. 11. is uſed, which may be ſupported by means of the perforated board DE, at the

proper depth in the veſſel FG, to draw off all the liquor required into the receiver LM. The principles and application of this uſeful inſtrument are ſo well known, as to need no explanation.

SECT. III.

Of Filtration.

A filtre is a ſpecies of very fine ſieve, which is permeable to the particles of fluids, but through which the particles of the fineſt powdered ſolids are incapable of paſſing; hence its uſe in ſeparating fine powders from ſuſpenſion in fluids. In pharmacy, very cloſe and fine woollen cloths are chiefly uſed for this operation; theſe are commonly formed in a conical ſhape, Pl. II. Fig. 2. which has the advantage of uniting all the liquor which drains through into a point A, where it may be readily collected in a narrow-mouthed veſſel. In large pharmaceutical laboratories, this filtering bag is ſtretched upon a wooden-ſtand, Pl. II. Fig. 1.

For the purpoſes of chemiſtry, as it is requiſite to have the filtres perfectly clean, unſized paper is ſubſtituted inſtead of cloth or flannel; through

through this ſubſtance, no ſolid body, however finely it be powdered, can penetrate, and fluids percolate through it with the greateſt readineſs. As paper breaks eaſily when wet, various methods of ſupporting it are uſed according to circumſtances. When a large quantity of fluid is to be filtrated, the paper is ſupported by the frame of wood, Pl. II. Fig. 3. ABCD, having a piece of coarſe cloth ſtretched over it, by means of iron-hooks. This cloth muſt be well cleaned each time it is uſed, or even new cloth muſt be employed, if there is reaſon to ſuſpect its being impregnated with any thing which can injure the ſubſequent operations. In ordinary operations, where moderate quantities of fluid are to be filtrated, different kinds of glaſs-funnels are uſed for ſupporting the paper, as repreſented Pl. II. Fig. 5, 6, and 7. When ſeveral filtrations muſt be carried on at once, the board or ſhelf AB, Fig. 9. ſupported upon ſtands C and D, and pierced with round holes, is very convenient for containing the funnels.

Some liquors are ſo thick and clammy, as not to be able to penetrate through paper without ſome previous preparation, ſuch as clarification by means of white of eggs, which, being mixed with the liquor, coagulates when brought to boil, and entangling the greater part of the impurities of the liquor, riſes with them to the ſurface in the ſtate of ſcum. Spirituous and vinous

nous liquors may be clarified in the ſame manner by means of iſinglaſs diſſolved in water, which coagulates by the action of the alcohol without the aſſiſtance of heat.

As moſt of the acids are produced by diſtillation, and are conſequently clear, we have rarely any occaſion to filtrate them ; but if, at any time, concentrated acids require this operation, it is impoſſible to employ paper, which would be corroded and deſtroyed by the acid. For this purpoſe, pounded glaſs, or rather quartz or rock-cryſtal, broke in pieces, and groſsly powdered, anſwers very well ; a few of the larger pieces are put in the neck of the funnel, theſe are covered with the ſmaller pieces, the finer powder is placed over all, and the acid is poured on at top. For the ordinary purpoſes of ſociety, river-water is frequently filtrated by means of clean-waſhed ſand, to ſeparate its impurities, or by means of certain porous ſtones, called filtering ſtones, cut into a convenient form.

SECT. IV.

Of Decantation.

This operation is often ſubſtitûted, inſtead of filtration, for ſeparating ſolid particles which are diffuſed

diffufed through liquors. Thefe are allowed to fettle in conical veffels, ABCDE, Pl. II. Fig. 10. the diffufed matters gradually fubfide, and the clear fluid is gently poured off. If the fediment be extremely light, and apt to mix again with the fluid by the flighteft motion, the fyphon, Fig. 11. is ufed, inftead of decantation, for drawing off the clear fluid.

In experiments, where the weight of the precipitate muft be rigoroufly afcertained, decantation is preferable to filtration, providing the precipitate be feveral times wafhed in a confiderable proportion of water. The weight of the precipitate may indeed be afcertained, by carefully weighing the filtre before and after the operation; but, when the quantity of precipitate is fmall, the different proportions of moifture retained by the paper, in a greater or leffer degree of exficcation, may prove a material fource of error, which ought carefully to be guarded againft.

CHAP.

CHAP. V.

Of Chemical Means for ſeparating the Particles of Bodies from each other, without Decompoſition, and for uniting them again.

I Have already ſhewn that there are two methods of dividing the particles of bodies, the *mechanical* and *chemical*. The former only ſeparates a ſolid maſs into a great number of ſmaller maſſes; and for theſe purpoſes various ſpecies of forces are employed, according to circumſtances, ſuch as the ſtrength of man or of animals, the weight of water applied through the means of hydraulic engines, the expanſive power of ſteam, the force of the wind, &c. By all or any of theſe mechanical powers, however, we can never reduce ſubſtances into powder beyond a certain degree of fineneſs; and the ſmalleſt particle produced in this way, though it ſeems very minute to our organs, is ſtill in fact a mountain, when compared with the ultimate elementary particles of the pulverized ſubſtance.

The chemical agents, on the contrary, divide bodies into their primitive particles. If, for inſtance, a neutral ſalt be acted upon by theſe, it is divided, as far as is poſſible, without ceaſing

to

to be a neutral ſalt. In this Chapter, I mean to give examples of this kind of diviſion of bodies, to which I ſhall add ſome account of the relative operations.

SECT. I.

Of the Solution of Salts.

In chemical language, the terms of *ſolution* and *diſſolution* have long been confounded, and have very improperly been indiſcriminately employed for expreſſing both the diviſion of the particles of a ſalt in a fluid, ſuch as water, and the diviſion of a metal in an acid. A few reflections upon the effects of theſe two operations will ſuffice to ſhow that they ought not to be confounded together. In the ſolution of ſalts, the ſaline particles are only ſeparated from each other, while neither the ſalt nor the water are at all decompoſed; for we are able to recover both the one and the other in the ſame quantity as before the operation. The ſame thing takes place in the ſolution of reſins in alcohol. During metallic diſſolutions, on the contrary, a decompoſition, either of the acid, or of the water which dilutes it, always takes place; the metal combines with oxygen, and is changed into

into an oxyd, and a gaseous substance is disengaged; so that in reality none of the substances employed remain, after the operation, in the some state they were in before. This article is entirely confined to the consideration of solution.

To understand properly what takes place during the solution of salts, it is necessary to know, that, in most of these operations, two distinct effects are complicated together, viz. solution by water, and solution by caloric; and, as the explanation of most of the phenomena of solution depends upon the distinction of these two circumstances, I shall enlarge a little upon their nature.

Nitrat of potash, usually called nitre or saltpetre, contains very little water of crystallization, perhaps even none at all; yet this salt liquefies in a degree of heat very little superior to that of boiling water. This liquefaction cannot therefore be produced by means of the water of crystallization, but in consequence of the salt being very fusible in its nature, and from its passing from the solid to the liquid state of aggregation, when but a little raised above the temperature of boiling water. All salts are in this manner susceptible of being liquefied by caloric, but in higher or lower degrees of temperature. Some of these, as the acetites of potash and soda, liquefy with a very moderate heat, while others,

as

as ſulphat of potaſh, or of lime, &c. require the ſtrongeſt fires we are capable of producing. This liquefaction of ſalts by caloric produces exactly the ſame phenomena with the melting of ice; it is accompliſhed in each ſalt by a determinate degree of heat, which remains invariably the ſame during the whole time of the liquefaction. Caloric is employed, and becomes fixed during the melting of the ſalt, and is, on the contrary, diſengaged when the ſalt coagulates. Theſe are general phenomena, which univerſally occur during the paſſage of every ſpecies of ſubſtance from the ſolid to the fluid ſtate of aggregation, and from fluid to ſolid.

Theſe phenomena, ariſing from ſolution by caloric, are always leſs or more conjoined with thoſe which take place during ſolutions in water. We cannot pour water upon a ſalt, on purpoſe to diſſolve it, without employing a compound ſolvent, both water and caloric; hence we may diſtinguiſh ſeveral different caſes of ſolution, according to the nature and mode of exiſtence of each ſalt. If, for inſtance, a ſalt be difficultly ſoluble in water, and readily ſo by caloric, it evidently follows, that this ſalt will be ſcantily ſoluble in cold water, and conſiderably in hot water; ſuch is nitrat of potaſh, and more eſpecially oxygenated muriat of potaſh. If another ſalt be little ſoluble both in water and caloric, the difference of its ſolubility in cold and warm

water

water will be very inconſiderable; ſulphat of lime is of this kind. From theſe conſiderations, it follows, that there is a neceſſary relation between the following circumſtances; the ſolubility of a ſalt in cold water, its ſolubility in boiling water, and the degree of temperature at which the ſame ſalt liquefies by caloric, unaſſiſted by water; and that the difference of ſolubility in hot and cold water is ſo much greater in proportion to its ready ſolution in caloric, or in proportion to its ſuſceptibility of liquefying in a low degree of temperature.

The above is a general view of ſolution; but, for want of particular facts, and ſufficiently exact experiments, it is ſtill nothing more than an approximation towards a particular theory. The means of completing this part of chemical ſcience is extremely ſimple; we have only to aſcertain how much of each ſalt is diſſolved by a certain quantity of water at different degrees of temperature; and as, by the experiments publiſhed by Mr de la Place and me, the quantity of caloric contained in a pound of water at each degree of the thermometer is accurately known, it will be very eaſy to determine, by ſimple experiments, the proportion of water and caloric required for ſolution by each ſalt, what quantity of caloric is abſorbed by each at the moment of liquifaction, and how much is diſengaged at the moment of cryſtallization. Hence the reaſon why

why ſalts are more rapidly ſoluble in hot than in cold water is perfectly evident. In all ſolutions of ſalts, caloric is employed; when that is furniſhed intermediately from the ſurrounding bodies, it can only arrive ſlowly to the ſalt; whereas this is greatly accelerated when the requiſite caloric exiſts ready combined with the water of ſolution.

In general, the ſpecific gravity of water is augmented by holding ſalts in ſolution; but there are ſome exceptions to the rule. Some time hence, the quantities of radical, of oxygen, and of baſe, which conſtitute each neutral ſalt, the quantity of water and caloric neceſſary for ſolution, the increaſed ſpecific gravity communicated to water, and the figure of the elementary particles of the cryſtals, will all be accurately known. From theſe all the circumſtances and phenomena of cryſtallization will be explained, and by theſe means this part of chemiſtry will be completed. Mr Seguin has formed the plan of a thorough inveſtigation of this kind, which he is extremely capable of executing.

The ſolution of ſalts in water requires no particular apparatus; ſmall glaſs-phials of different ſizes, Pl. II. Fig. 16. and 17. pans of earthenware, A, Fig. 1. and 2. long-necked matraſſes, Fig. 14. and pans or baſons of copper or of ſilver, Fig. 13. and 15. anſwer very well for theſe operations.

SECT. II.

Of Lixiviation.

This is an operation ufed in chemiftry and manufactures for feparating fubftances which are foluble in water from fuch as are infoluble. The large vat or tub, Pl. II. Fig. 12. having a hole D near its bottom, containing a wooden-fpigot and foffet, or metallic ftop-cock DE, is generally ufed for this purpofe. A thin ftratum of ftraw is placed at the bottom of the tub; over this, the fubftance to be lixiviated is laid and covered by a cloth, then hot or cold water, according to the degree of folubility of the faline matter, is poured on. When the water is fuppofed to have diffolved all the faline parts, it is let off by the ftop-cock; and, as fome of the water charged with falt neceffarily adheres to the ftraw and infoluble matters, feveral frefh quantities of water are poured on. The ftraw ferves to fecure a proper paffage for the water, and may be compared to the ftraws or glafs rods ufed in filtrating, to keep the paper from touching the fides of the funnel. The cloth which is laid over the matters under lixiviation prevents the water from

making;

making a hollow in theſe ſubſtances where it is poured on, through which it might eſcape without acting upon the whole maſs.

This operation is leſs or more imitated in chemical experiments; but as in theſe, eſpecially with analytical views, greater exactneſs is required, particular precautions muſt be employed, ſo as not leave any ſaline or ſoluble part in the reſiduum. More water muſt be employed than in ordinary lixiviations, and the ſubſtances ought to be previouſly ſtirred up in the water before the clear liquor is drawn off, otherwiſe the whole maſs might not be equally lixiviated, and ſome parts might even eſcape altogether from the action of the water. We muſt likewiſe employ freſh portions of water in conſiderable quantity, until it comes off entirely free from ſalt, which we may aſcertain by means of the hydrometer formerly deſcribed.

In experiments with ſmall quantities, this operation is conveniently performed in jugs or matraſſes of glaſs, and by filtrating the liquor through paper in a glaſs-funnel. When the ſubſtance is in larger quantity, it may be lixiviated in a kettle of boiling water, and filtrated through paper ſupported by cloth in a wooden frame, Pl. II. Fig. 3. and 4.; and operations in the large way, the tub already mentioned muſt be uſed.

SECT. III.

Of Evaporation.

This operation is ufed for feparating two fubftances from each other, of which one at leaft muft be fluid, and whofe degrees of volatility are confiderably different. By this means we obtain a falt, which has been diffolved in water, in its concrete form ; the water, by heating, becomes combined with caloric, which renders it volatile, while the particles of the falt being brought nearer to each other, and within the fphere of their mutual attraction, unite into the folid ftate.

As it was long thought that the air had great influence upon the quantity of fluid evaporated, it will be proper to point out the errors which this opinion has produced. There certainly is a conftant flow evaporation from fluids expofed to the free air ; and, though this fpecies of evaporation may be confidered in fome degree as a folution in air, yet caloric has a confiderable influence in producing it, as is evident from the refrigeration which always accompanies this procefs ; hence we may confider this gradual evaporation as a compound folution made partly in air,

air, and partly in caloric. But the evaporation which takes place from a fluid kept continually boiling, is quite different in its nature, and in it the evaporation produced by the action of the air is exceedingly inconſiderable in compariſon with that which is occaſioned by caloric. This latter ſpecies may be termed *vaporization* rather than *evaporation*. This proceſs is not accelerated in proportion to the extent of evaporating ſurface, but in proportion to the quantities of caloric which combine with the fluid. Too free a current of cold air is often hurtful to this proceſs, as it tends to carry off caloric from the water, and conſequently retards its converſion into vapour. Hence there is no inconvenience produced by covering, in a certain degree, the veſſels in which liquids are evaporated by continual boiling, provided the covering body be of ſuch a nature as does not ſtrongly draw off the caloric, or, to uſe an expreſſion of Dr Franklins, provided it be a bad conductor of heat. In this caſe, the vapours eſcape through ſuch opening as is left, and at leaſt as much is evaporated, frequently more than when free acceſs is allowed to the external air.

As during evaporation the fluid carried off by caloric is entirely loſt, being ſacrificed for the ſake of the fixed ſubſtances with which it was combined, this proceſs is only employed where the fluid is of ſmall value, as water, for inſtance.

 But,

But, when the fluid is of more confequence, we have recourfe to diftillation, in which procefs we preferve both the fixed fubftance and the volatile fluid. The veffels employed for evaporation are bafons or pans of copper, filver or lead, Pl. II. Fig. 13. and 15. or capfules of glafs, porcelain, or ftone-ware, Pl. II. A, Fig. 1. and 2. Pl. III. Fig. 3. and 4. The beft utenfils for this purpofe are made of the bottoms of glafs-retorts and matraffes, as their equal thinnefs renders them more fit than any other kind of glafs-veffel for bearing a brifk fire, and fudden alterations of heat and cold, without breaking.

As the method of cutting thefe glafs-veffels is no where defcribed in books, I fhall here give a defcription of it, that they may be made by chemifts for themfelves out of fpoiled retorts, matraffes, and recipients, at a much cheaper rate than any which can be procured from glafs-manufacturers. The inftrument, Pl. III. Fig. 5. confifting of an iron-ring A C, fixed to the rod A B, having a wooden handle D, is employed as follows: Make the ring red hot in the fire, and put it upon the matrafs G, Fig. 6. which is to be cut; when the glafs is fufficiently heated, throw on a little cold water, and it will generally break exactly at the circular line heated by the ring.

Small flafks or phials of thin glafs are exceeding good veffels for evaporating fmall quantities of fluid; they are very cheap, and ftand the fire remarkably.

remarkably. One or more of theſe may be placed upon a ſecond grate above the furnace, Pl. III. Fig. 2. where they will only experience a gentle heat. By this means a great number of experiments may be carried on at one time. A glaſs-retort, placed on a ſand-bath, and covered with a dome of baked earth, Pl. III. Fig. 1. anſwers pretty well for evaporations; but in this way it is always conſiderably ſlower, and is even liable to accidents; as the ſand heats unequally, and the glaſs cannot dilate in the ſame unequal manner, the retort is very liable to break. Sometimes the ſand ſerves exactly the office of the iron ring formerly mentioned; for, if a ſingle drop of vapour, condenſed into liquid, happens to fall upon the heated part of the veſſel, it breaks circularly at that place. When a very intenſe fire is neceſſary, earthen crucibles may be uſed; but we generally uſe the word *evaporation* to expreſs what is produced by the temperature of boiling water, or not much higher.

SECT. IV.

Of Cryſtallization.

In this proceſs the integrant parts of a ſolid body, ſeparated from each other by the intervention of a fluid, are made to exert the mutual attraction of aggregation, ſo as to coaleſce and reproduce a ſolid maſs. When the particles of a body are only ſeparated by caloric, and the ſubſtance is thereby retained in the liquid ſtate, all that is neceſſary for making it cryſtallize, is to remove a part of the caloric which is lodged between its particles, or, in other words, to cool it. If this refrigeration be ſlow, and the body be at the ſame time left at reſt, its particles aſſume a regular arrangement, and cryſtallization, properly ſo called, takes place; but, if the refrigeration is made rapidly, or if the liquor be agitated at the moment of its paſſage to the concrete ſtate, the cryſtallization is irregular and confuſed.

The ſame phenomena occur with watery ſolutions, or rather in thoſe made partly in water, and partly by caloric. So long as there remains a ſufficiency of water and caloric to keep the particles of the body aſunder beyond the ſphere of

of their mutual attraction, the ſalt remains in the fluid ſtate; but whenever either caloric or water is not preſent in ſufficient quantity, and the attraction of the particles for each other becomes ſuperior to the power which keeps them aſunder, the ſalt recovers its concrete form, and the cryſtals produced are the more regular in proportion as the evaporation has been ſlower and more tranquilly performed.

All the phenomena we formerly mentioned as taking place during the ſolution of ſalts, occur in a contrary ſenſe during their cryſtallization. Caloric is diſengaged at the inſtant of their aſſuming the ſolid ſtate, which furniſhes an additional proof of ſalt being held in ſolution by the compound action of water and caloric. Hence to cauſe ſalts to cryſtallize which readily liquefy by means of caloric, it is not ſufficient to carry off the water which held them in ſolution, but the caloric united to them muſt likewiſe be removed. Nitrat of potaſh, oxygenated muriat of potaſh, alum, ſulphat of ſoda, &c. are examples of this circumſtance, as, to make theſe ſalts cryſtallize, refrigeration muſt be added to evaporation. Such ſalts, on the contrary, as require little caloric for being kept in ſolution, and which, from that circumſtance, are almoſt equally ſoluble in cold and warm water, are cryſtallizable by ſimply carrying off the water which holds them in ſolution, and

even

even recover their ſolid ſtate in boiling water; ſuch are ſulphat of lime, muriat of potaſh and of ſoda, and ſeveral others.

The art of refining ſaltpetre depends upon theſe properties of ſalts, and upon their different degrees of ſolubility in hot and cold water. This ſalt, as produced in the manufactories by the firſt operation, is compoſed of many different ſalts; ſome are deliqueſcent, and not ſuſceptible of being cryſtallized, ſuch as the nitrat and muriat of lime; others are almoſt equally ſoluble in hot and cold water, as the muriats of potaſh and of ſoda; and laſtly, the ſaltpetre, or nitrat of potaſh, is greatly more ſoluble in hot than it is in cold water. The operation is begun by pouring upon this mixture of ſalts, as much water as will hold even the leaſt ſoluble, the muriats of ſoda and of potaſh, in ſolution; ſo long as it is hot, this quantity readily diſſolves all the ſaltpetre, but upon cooling, the greater part of this ſalt cryſtallizes, leaving about a ſixth part remaining diſſolved, and mixed with the nitrat of lime and the two muriats. The nitre obtained by this proceſs is ſtill ſomewhat impregnated with other ſalts, becauſe it has been cryſtallized from water in which theſe abound: It is completely purified from theſe by a ſecond ſolution in a ſmall quantity of boiling water and ſecond cryſtallization. The water remaining after theſe cryſtallizations of nitre is ſtill loaded with a mixture

ture of ſaltpetre, and other ſalts; by farther evaporation, crude ſaltpetre, or rough-petre, as the workmen call it, is procured from it, and this is purified by two freſh ſolutions and cryſtallizations.

The deliqueſcent earthy ſalts which do not contain the nitric acid are rejected in this manufacture; but thoſe which conſiſt of that acid neutralized by an earthy baſe are diſſolved in water, the earth is precipitated by means of potaſh, and allowed to ſubſide; the clear liquor is then decanted, evaporated, and allowed to cryſtallize. The above management for refining ſaltpetre may ſerve as a general rule for ſeparating ſalts from each other which happen to be mixed together. The nature of each muſt be conſidered, the proportion in which each diſſolves in given quantities of water, and the different ſolubility of each in hot and cold water. If to theſe we add the property which ſome ſalts poſſeſs, of being ſoluble in alcohol, or in a mixture of alcohol and water, we have many reſources for ſeparating ſalts from each other by means of cryſtallization, though it muſt be allowed, that it is extremely difficult to render this ſeparation perfectly complete.

The veſſels uſed for cryſtallization are pans of earthen ware, A, Pl. II. Fig. 1. and 2. and large flat-diſhes, Pl. III. Fig. 7. When a ſaline ſolution is to be expoſed to a ſlow evaporation in

in the heat of the atmoſphere, with free acceſs of air, veſſels of ſome depth, Plate III. Fig. 3. muſt be employed, that there may be a conſiderable body of liquid ; by this means the cryſtals produced are of conſiderable ſize, and remarkably regular in their figure.

Every ſpecies of ſalt cryſtallizes in a peculiar form, and even each ſalt varies in the form of its cryſtals, according to circumſtances, which take place during cryſtallization. We muſt not from thence conclude, that the ſaline particles of each ſpecies are indeterminate in their figures: The primitive particles of all bodies, eſpecially of ſalts, are perfectly conſtant in their ſpecific forms ; but the cryſtals which form in our experiments are compoſed of congeries of minute particles, which, though perfectly equal in ſize and ſhape, may aſſume very diſſimilar arrangements, and conſequently produce a vaſt variety of regular forms, which have not the ſmalleſt apparent reſemblance to each other, nor to the original cryſtal. This ſubject has been very ably treated by the Abbé Haüy, in ſeveral memoirs preſented to the Academy, and in his work upon the ſtructure of cryſtals : It is only neceſſary to extend generally to the claſs of ſalts the principles he has particularly applied to ſome cryſtallized ſtones.

SECT.

SECT. V.

Of Simple Diſtillation.

As diſtillation has two diſtinct objects to accompliſh, it is diviſible into ſimple and compound; and, in this ſection, I mean to confine myſelf entirely to the former. When two bodies, of which one is more volatile than the other, or has more affinity to caloric, are ſubmitted to diſtillation, our intention is to ſeparate them from each other: The more volatile ſubſtance aſſumes the form of gas, and is afterwards condenſed by refrigeration in proper veſſels. In this caſe diſtillation, like evaporation, becomes a ſpecies of mechanical operation, which ſeparates two ſubſtances from each other without decompoſing or altering the nature of either. In evaporation, our only object is to preſerve the fixed body, without paying any regard to the volatile matter; whereas, in diſtillation, our principal attention is generally paid to the volatile ſubſtance, unleſs when we intend to preſerve both the one and the other. Hence, ſimple diſtillation is nothing more than evaporation produced in cloſe veſſels.

The moſt ſimple diſtilling veſſel is a ſpecies of

of bottle or matrafs, A, Pl. III. Fig. 8. which has been bent from its original form BC to BD, and is then called a retort; when ufed, it is placed either in a reverberatory furnace, Pl. XIII. Fig. 2. or in a fand-bath under a dome of baked earth, Pl. III. Fig. 1. To receive and condenfe the products we adapt a recipient, E, Pl. III. Fig. 9. which is luted to the retort.

Sometimes, more efpecially in pharmaceutical operations, the glafs or ftone ware cucurbit, A, with its capital B, Pl. III. Fig. 12. or the glafs alembic and capital, Fig. 13. of one piece, is employed. This latter is managed by means of a tubulated opening T, fitted with a ground ftopper of cryftal; the capital, both of the cucurbit and alembic, has a furrow or trench, *r r*, intended for conveying the condenfed liquor into the beak *r*S, by which it runs out. As, in almoft all diftillations, expanfive vapours are produced, which might burft the veffels employed, we are under the neceffity of having a fmall hole, T, Fig. 9. in the balloon or recipient, through which thefe may find vent; hence, in this way of diftilling, all the products which are permanently aëriform are entirely loft, and even fuch as difficultly lofe that ftate have not fufficient fpace to condenfe in the balloon: This apparatus is not, therefore, proper for experiments of inveftigation, and can only be admitted in the ordinary operations of the laboratory or in pharmacy.

pharmacy. In the article appropriated for compound diſtillation, I ſhall explain the various methods which have been contrived for preſerving the whole products from bodies in this proceſs.

As glaſs or earthen veſſels are very brittle, and do not readily bear ſudden alterations of heat and cold, every well-regulated laboratory ought to have one or more alembics of metal for diſtilling water, ſpiritous liquors, eſſential oils, &c. This apparatus conſiſts of a cucurbit and capital of tinned copper or braſs, Pl. III. Fig. 15. and 16. which, when judged proper, may be placed in the water-bath, D, Fig. 17. In diſtillation, eſpecially of ſpiritous liquors, the capital muſt be furniſhed with a refrigeratory, SS, Fig. 16. kept continually filled with cold water; when the water becomes heated, it is let off by the ſtop-cock, R, and renewed with a freſh ſupply of cold water. As the fluid diſtilled is converted into gas by means of caloric furniſhed by the fire of the furnace, it is evident that it could not condenſe, and, conſequently, that no diſtillation, properly ſpeaking, could take place, unleſs it is made to depoſite in the capital all the caloric it received in the cucurbit; with this view, the ſides of the capital muſt always be preſerved at a lower temperature than is neceſſary for keeping the diſtilling ſubſtance in the ſtate of gas, and the water in the

the refrigeratory is intended for this purpofe. Water is converted into gas by the temperature of 212°, alcohol by 182.75°, and ether by 104°; hence thefe fubftances cannot be diftilled, or rather they will fly off in the ftate of gas, unlefs the temperature of the refrigeratory be kept under thefe refpective degrees.

In the diftillation of fpiritous, and other expanfive liquors, the above-defcribed refrigeratory is not fufficient for condenfing all the vapours which arife; in this cafe, therefore, inftead of receiving the diftilled liquor immediately from the beak TU, of the capital into a recipient, a worm is interpofed between them. This inftrument is reprefented Pl. III. Fig. 18. contained in a worm-tub of tinned copper; it confifts of a metallic tube bent into a confiderable number of fpiral revolutions. The veffel which contains the worm is kept full of cold water, which is renewed as it grows warm. This contrivance is employed in all diftilleries of fpirits, without the intervention of a capital and refrigeratory, properly fo called. The one reprefented in the plate is furnifhed with two worms, one of them being particularly appropriated to diftillations of odoriferous fubftances.

In fome fimple diftillations it is neceffary to interpofe an adopter between the retort and receiver, as fhewn Pl. III. Fig. 11. This may ferve two different purpofes; either to feparate

two

two products of different degrees of volatility; or to remove the receiver to a greater diſtance from the furnace, that it may be leſs heated. But theſe, and ſeveral other more complicated inſtruments of ancient contrivance, are far from producing the accuracy requiſite in modern chemiſtry, as will be readily perceived when I come to treat of compound diſtillation.

" In conſequence of the duties on the Scottiſh diſtilleries having lately been collected by an annual ſum, proportional to the contents of the ſtill, it has been found profitable to hurry the proceſs as much as poſſible; and, for this purpoſe, the ſtills have been made exceſſively broad and ſhallow, with very lofty heads: By the breadth and ſhallowneſs, the caloric of the fuel acts very quickly, having much ſurface, and little reſiſtance of incumbent liquid; and the height of the head prevents any part of the undiſtilled liquid from boiling over. In this way, it is found that the contents of large ſtills may be diſtilled off with aſtoniſhing quickneſs; perhaps conſiderably above 200 times every 24 hours."—T.

SECT. VI.

Of Sublimation.

This term is applied to the diſtillation of ſubſtances which condenſe in a concrete or ſolid form, ſuch as the ſublimation of ſulphur, and of muriat of ammoniac, or ſal ammoniac These operations may be conveniently performed in the ordinary diſtilling veſſels already deſcribed, though, in the ſublimation of ſulphur, a ſpecies of veſſels, named Aludels, have been uſually employed. Theſe are veſſels of ſtone or porcelain ware, which adjuſt to each other over a cucurbit containing the ſulphur to be ſublimed. One of the beſt ſubliming veſſels, for ſubſtances which are not very volatile, is a flaſk, or phial of glaſs, ſunk about two-thirds into a ſand-bath; but in this way we are apt to loſe a part of the products. When theſe are wiſhed to be entirely preſerved, we muſt have recourſe to the pneumato-chemical diſtilling apparatus, to be deſcribed in the following chapter.

CHAP. VI.

Of Pneumato-chemical Diſtillations, Metallic Diſſolutions, and ſome other Operations which require very complicated Inſtruments.

SECT. I.

Of Compound and Pneumato-chemical Diſtillations.

IN the preceding chapter, I have only treated of diſtillation as a ſimple operation, by which two ſubſtances, differing in their degrees of volatility, may be ſeparated from each other; but diſtillation often actually decompoſes the ſubſtances ſubmitted to its action, and becomes one of the moſt complicated operations in chemiſtry. In every diſtillation, the ſubſtance diſtilled muſt be brought to the ſtate of gas, in the cucurbit or retort, by combination with caloric: In ſimple diſtillation, this caloric is given out in the refrigeratory or in the worm, and the ſubſtance again recovers its liquid or ſolid form; but the ſubſtances ſubmitted to compound diſtillation

are abſolutely decompounded ; one part, as for inſtance the carbon they contain, remains fixed in the retort, and all the reſt of the elements are reduced to gaſes of different kinds. Some of theſe gaſes are ſuſceptible of being condenſed, and of recovering their ſolid or liquid forms, while others are permanently aëriform ; one part of theſe are abſorbable by water, ſome by the alkalics, and others are not ſuſceptible of being abſorbed at all. An ordinary diſtilling apparatus, ſuch as has been deſcribed in the preceding chapter, is quite inſufficient for retaining or for ſeparating theſe diverſified products, and we are obliged to have recourſe, for this purpoſe, to methods of a more complicated nature.

The apparatus I am about to deſcribe is calculated for the moſt complicated diſtillations, and may be ſimplified or extended according to circumſtances. It conſiſts of a tubulated glaſs-retort A, Pl. IV Fig. 1. having its beak fitted to a tubulated balloon or recipient BC ; to the upper orifice D of the balloon a bent tube DE*fg* is adjuſted, which, at its other extremity *g*, is plunged into the liquor contained in the bottle L, with three necks *xxx*. Three other ſimilar bottles are connected with this firſt one, by means of three ſimilar bent tubes diſpoſed in the ſame manner ; and the fartheſt neck of the laſt bottle is connected with a jar in a pneumato-chemical apparatus, by means of a bent

tube

tube *. A determinate weight of diſtilled water is uſually put into the firſt bottle, and the other three have each a ſolution of pure potaſh in water. The weight of all theſe bottles, and of the water and alkaline ſolution they contain, muſt be accurately aſcertained. Every thing being thus diſpoſed, the junctures between the retort and recipient, and of the tube D of the latter, muſt be luted with fat lute, covered over with ſlips of linen, ſpread with lime and white of eggs; all the other junctures are to be ſecured by a lute made of wax and roſin melted together.

When all theſe diſpoſitions are completed, and when, by means of heat applied to the retort A, the ſubſtance it contains becomes decompoſed, it is evident that the leaſt volatile products muſt condenſe or ſublime in the beak or neck of the retort itſelf, where moſt of the concrete ſubſtances will fix themſelves. The more volatile ſubſtances, as the lighter oils, ammoniac, and ſeveral others, will condenſe in the recipient GC, whilſt the gaſes, which are not ſuſceptible of condenſation by cold, will paſs on by the tubes, and boil up through the liquors in the ſeveral bottles. Such as are abſorbable by

* The repreſentation of this apparatus, Pl IV. Fig. 1. will convey a much better idea of its diſpoſition than can poſſibly be given by the moſt laboured deſcription.—T.

by water will remain in the firſt bottle, and thoſe which pure alkali can abſorb will remain in the others; while ſuch gaſes as are not ſuſceptible of abſorption, either by water or alkalies, will eſcape by the tube RM, at the end of which they may be received into jars in a pneumato-chemical apparatus. The carbon and fixed earth, &c. which form the ſubſtance or reſiduum, anciently called *caput mortuum*, remain behind in the retort.

In this manner of operating, we have always a very material proof of the accuracy of the analyſis, as the whole weights of the products taken together, after the proceſs is finiſhed, muſt be exactly equal to the weight of the original ſubſtance ſubmitted to diſtillation. Hence, for inſtance, if we have operated upon eight ounces of ſtarch or gum arabic, the weight of the charry reſiduum in the retort, together with that of all the products gathered in its neck and the balloon, and of all the gas received into the jars by the tube RM added to the additional weight acquired by the bottles, muſt, when taken together, be exactly eight ounces. If the product be leſs or more, it proceeds from error, and the experiment muſt be repeated until a ſatisfactory reſult be procured, which ought not to differ more than ſix or eight grains in the pound from the weight of the ſubſtance ſubmitted to experiment.

In

In experiments of this kind, I for a long time met with an almoſt inſurmountable difficulty, which muſt at laſt have obliged me to deſiſt altogether, but for a very ſimple method of avoiding it, pointed out to me by Mr Haſſenfratz. The ſmalleſt diminution in the heat of the furnace, and many other circumſtances inſeparable from this kind of experiments, cauſe frequent reabſorptions of gas: when this occors, the water in the ciſtern of the pneumato-chemical apparatus ruſhes into the laſt bottle through the tube RM; the ſame circumſtance happens from one bottle into another, and the fluid is often forced even into the recipient C. This accident is prevented by uſing bottles having three necks, as repreſented in the plate, into one of which, in each bottle, a capillary glaſs tube *St*, *st*, *st*, *st*, is adapted, ſo as to have its lower extremity *t* immerſed in the liquor. If any abſorption takes place, either in the retort, or in any of the bottles, a ſufficient quantity of external air enters, by means of theſe tubes, to fill up the void; and we get rid of the inconvenience at the price of having a ſmall portion of common air mixed with the products of the experiment, which is thereby prevented from failing altogether. Though theſe tubes admit the external air, they cannot permit any of the gaſeous ſubſtances to eſcape, as they are always ſhut below by the water of the bottles.

It is evident that, in the courſe of experiments with this apparatus, the liquor of the bottles muſt riſe in theſe tubes in proportion to the preſſure ſuſtained by the gas or air contained in the bottles; and this preſſure is determined by the height and gravity of the column of fluid contained in all the ſubſequent bottles. If we ſuppoſe that each bottle contains three inches of fluid, and that there are three inches of water in the ciſtern of the connected apparatus above the orifice of the tube RM, and allowing the gravity of the fluids to be only equal to that of that water, it follows that the air in the firſt bottle muſt ſuſtain a preſſure equal to twelve inches of water; the water muſt therefore riſe twelve inches in the tube S, connected with the firſt bottle, nine inches in that belonging to the ſecond, ſix inches in the third, and three in the laſt; wherefore theſe tubes muſt be made ſomewhat more than twelve, nine, ſix, and three inches long reſpectively, allowance being made for oſcillatory motions, which often take place in the liquids It is ſometimes neceſſary to introduce a ſimilar tube between the retort and recipient; and as the tube is not immerſed in fluid at its lower extremity, until ſome has collected in the progreſs of the diſtillation, its upper end muſt be ſhut at firſt with a little lute, ſo as to be opened according to neceſſity, or after there

there is sufficient liquid in the recipient to secure its lower extremity.

This apparatus cannot be used in very accurate experiments, when the substances intended to be operated upon have a very rapid action upon each other, or when one of them can only be introduced in small successive portions, as in such as produce violent effervescence when mixed together. In such cases, we employ a tubulated retort A, Pl. VII. Fig. 1. into which one of the substances is introduced, preferring always the solid body, if any such is to be treated, we then lute to the opening of the retort a bent tube BCDA, terminating at its upper extremity B in a funnel, and at its other end A in a capillary opening. The fluid material of the experiment is poured into the retort by means of this funnel, which must be made of such a length, from B to C, that the column of liquid introduced may counterbalance the resistance produced by the liquors contained in all the bottles, Pl. IV. Fig. 1.

Those who have not been accustomed to use the above-described distilling apparatus, may perhaps be startled at the great number of openings which require luting, and the time necessary for making all the previous preparations in experiments of this kind. It is very true that, if we take into account all the necessary weighings of materials and products, both before and after

after the experiments, theſe preparatory and ſucceeding ſteps require much more time and attention than the experiment itſelf. But, when the experiment ſucceeds properly, we are well rewarded for all the time and trouble beſtowed, as, by one proceſs carried on in this accurate manner, much more juſt and extenſive knowledge is acquired, of the nature of the vegetable or animal ſubſtance thus ſubmitted to inveſtigation, than by many weeks aſſiduous labour in the ordinary method of proceeding.

When in want of bottles with three orifices, thoſe with two may be uſed; it is even poſſible to introduce all the three tubes at one opening, ſo as to employ ordinary wide mouthed bottles, provided the opening be ſufficiently large. In this caſe we muſt carefully fit the bottles with corks very accurately cut, and boiled in a mixture of oil, wax, and turpentine. Theſe corks are pierced with the neceſſary holes for receiving the tubes, by means of a round file, as in Pl. IV. Fig. 8.

SECT.

SECT. II.

Of Metallic Diſſolutions.

I have already pointed out the difference between ſolution of ſalts in water and metallic diſſolutions. The former requires no particular veſſels, whereas the latter requires very complicated veſſels of late invention, that we may not loſe any of the products of the experiment, and may thereby procure truly concluſive reſults of the phenomena which occur. The metals, in general, diſſolve, in acids with efferveſcence, which is only a motion excited in the ſolvent by the diſengagement of a great number of bubbles of air or aëriform fluid, which proceed from the ſurface of the metal and break at the ſurface of the liquid.

Mr Cavendiſh and Dr Prieſtley were the firſt inventors of a proper apparatus for collecting theſe elaſtic fluids. That of Dr Prieſtley is extremely ſimple, and conſiſts of a bottle A, Pl. VII. Fig. 2. with its cork B, through which paſſes the bent glaſs-tube BC, which is engaged under a jar filled with water in the pneumato-chemical apparatus, or ſimply in a baſon full of water. The metal is firſt introduced into the bottle,

bottle, the acid is then poured over it, and the bottle is inſtantly cloſed with its cork and tube, as repreſented in the plate. But this apparatus has its inconveniencies. When the acid is much concentrated, or the metal much divided, the effervefcence begins before we have time to cork the bottle properly, and ſome gas eſcapes, by which we are prevented from aſcertaining the quantity diſengaged with rigorous exactneſs. In the next place, when we are obliged to employ heat, or when heat is produced by the proceſs, a part of the acid diſtils, and mixes with the water of the pneumato-chemical apparatus, by which means we are deceived in our calculation of the quantity of acid decompoſed. Beſides theſe, the water in the ciſtern of the apparatus abſorbs all the gas produced which is ſuſceptible of abſorption, and renders it impoſſible to collect theſe without loſs.

To remedy theſe inconveniencies, I at firſt uſed a bottle with two necks, Pl. VII. Fig. 3. into one of which the glaſs-funnel BC is luted ſo as to prevent any air eſcaping; a glaſs-rod DE is fitted with emery to the funnel, ſo as to ſerve the purpoſe of a ſtopper. When it is uſed, the matter to be diſſolved is firſt introduced into the bottle, and the acid is then permitted to paſs in as ſlowly as we pleaſe, by raiſing the glaſs-rod gently as often as is neceſſary until ſaturation is produced.

Another

Another method has been ſince employed, which ſerves the ſame purpoſe, and is preferable to the laſt deſcribed in ſome inſtances. This conſiſts in adapting to one of the mouths of the bottle A, Pl. VII. Fig. 4. a bent tube D E F G, having a capillary opening at D, and ending in a funnel at G. This tube is ſecurely luted to the mouth C of the bottle. When any liquid is poured into the funnel, it falls down to F; and, if a ſufficient quantity be added, it paſſes by the curvature E, and falls ſlowly into the bottle, ſo long as freſh liquor is ſupplied at the funnel. The liquor can never be forced out of the tube, and no gas can eſcape through it, becauſe the weight of the liquid ſerves the purpoſe of an accurate cork.

To prevent any diſtillation of acid, eſpecially in diſſolutions accompanied with heat, this tube is adapted to the retort A, Pl. VII. Fig. 1. and a ſmall tubulated recipient, M, is applied, in which any liquor which may diſtil is condenſed On purpoſe to ſeparate any gas that is abſorbable by water, we add the double-necked bottle L, half filled with a ſolution of pure potaſh: the alkali abſorbs any carbonic acid gas, and uſually only one or two other gaſes paſs into the jar of the connected pneumato-chemical apparatus through the tube N O. In the firſt chapter of this third part we have directed how theſe are to be ſeparated and examined.

If

If one bottle of alkaline ſolution be not thought ſufficient, two, three, or more, may be added.

SECT. III.

Apparatus neceſſary in Experiments upon Vinous and Putrefactive Fermentations.

For theſe operations, a peculiar apparatus, eſpecially intended for this kind of experiment, is requiſite. The one I am about to deſcribe was finally adopted, as the beſt calculated for the purpoſe, after numerous corrections and improvements. It conſiſts of a large matraſs, A, Pl. X. Fig. 1. holding about twelve pints, with a cap of braſs *a b*, ſtrongly cemented to its mouth, and into which is ſcrewed a bent tube *c d*, furniſhed with a ſtop-cock *e*. To this tube is joined the glaſs recipient B, having three openings, one of which communicates with the bottle C, placed below it. To the poſterior opening of this recipient is fitted a glaſs-tube *g h i*, cemented at *g* and *i* to collets of braſs, and intended to contain a very deliqueſcent concrete neutral ſalt, ſuch as nitrat or muriat of lime, acetite of potaſh, &c. This tube communicates with two bottles D and E, filled to *x* and *y*, with a ſolution of pure potaſh.

All

All the parts of this machine are joined together by accurate ſcrews, and the touching parts have greaſed leather interpoſed, to prevent any paſſage of air. Each piece is likewiſe furniſhed with two ſtop-cocks, by which its two extremities may be cloſed, ſo that we can weigh each ſeparately at any period of the operation.

The fermentable matter, ſuch as ſugar, with a proper quantity of yeaſt, and diluted with water, is put into the matraſs. Sometimes, when the fermentation is too rapid, a conſiderable quantity of froth is produced, which not only fills the neck of the matraſs, but paſſes into the recipient, and from thence runs down into the bottle C. On purpoſe to collect this ſcum and muſt, and to prevent it from reaching the tube filled with deliqueſcent ſalts, the recipient and connected bottle are made of conſiderable capacity.

In the vinous fermentation, only carbonic acid gas is diſengaged, carrying with it a ſmall proportion of water in ſolution. A great part of this water is depoſited in paſſing through the tube *g h i*, which is filled with a deliqueſcent ſalt in groſs powder, and the quantity is aſcertained by the augmentation of the weight of the ſalt. The carbonic acid gas bubbles up through the alkaline ſolution in the bottle D, to which it is conveyed by the tube *k l m*. Any ſmall portion which may not be abſorbed by this firſt bottle,

bottle, is ſecured by the ſolution in the ſecond bottle E, ſo that nothing, in general, paſſes into the jar F, except the common air contained in the veſſels at the commencement of the experiment.

The ſame apparatus anſwers extremely well for experiments upon the putrefactive fermentation; but, in this caſe, a conſiderable quantity of hydrogen gas is diſengaged through the tube *q r s t u*, by which it is conveyed into the jar F; and, as this diſengagement is very rapid, eſpecially in ſummer, the jar muſt be frequently changed. Theſe putrefactive fermentations require conſtant attendance from the above circumſtance, whereas the vinous fermentation hardly needs any. By means of this apparatus, we can aſcertain, with great preciſion, the weights of the ſubſtances ſubmitted to fermentation, and of the liquid and aëriform products which are diſengaged. What has been already ſaid in Part I. Chap. XIII. upon the products of the vinous fermentation, may be conſulted.

SECT.

SECT. IV.

Apparatus for the Decompoſition of Water.

Having already given an account, in the firſt part of this work, of the experiments relative to the decompoſition of water, I ſhall avoid any unneceſſary repetitions, and only give a few ſummary obſervations upon the ſubject in this ſection. The principal ſubſtances which have the power of decompoſing water, are iron and charcoal; for which purpoſe, they require to be made red hot, otherwiſe the water is only reduced into vapour, and condenſes afterwards by refrigeration, without ſuſtaining the ſmalleſt alteration. In a red heat, on the contrary, iron or charcoal carry off the oxygen from its union with hydrogen; in the firſt caſe, black oxyd of iron is produced, and the hydrogen is diſengaged pure in form of gas; in the other caſe, carbonic acid gas is formed, which diſengages, mixed with the hydrogen gas, and this latter is commonly carbonated, or holds carbon in ſolution.

A muſket-barrel, without its breach-pin, anſwers exceedingly well for the decompoſition of water, by means of iron, and one ſhould be

 choſen

chofen of confiderable length, and pretty ftrong. When too fhort, fo as to run the rifk of heating the lute too much, a tube of copper muft be ftrongly foldered to one end. The barrel is placed in a long furnace, CDEF, Pl. VII. Fig. 11. fo as to have a few degrees of inclination from E to F; a glafs retort A, is luted to the upper extremity E, which contains water, and is placed upon the furnace VVXX. The lower extremity F is luted to a worm SS, which is connected with the tubulated bottle H, in which any water diftilled without decompofition, during the operation, collects, and the difengaged gas is carried by the tube KK to jars in a pneumato-chemical apparatus. Inftead of the retort, a funnel may be employed, having its lower part fhut by a ftopcock, through which the water is allowed to drop gradually into the gun-barrel. Immediately upon getting into contact with the heated part of the iron, the water is converted into fteam, and the experiment proceeds in the fame manner as if it were furnifhed in vapours from the retort.

In the experiment made by Mr Meufnier and me before a committee of the Academy, we ufed every precaution to obtain the greateft poffible precifion in the refult of our experiment, having even exhaufted all the veffels employed before we began, fo that the hydrogen gas obtained might be free from any mixture of azotic gas. The re-

fults

ſults of that experiment will hereafter be given at large in a particular memoir.

In numerous experiments, we are obliged to uſe tubes of glaſs, porcelain, or copper, inſtead of gun-barrels; but glaſs has the diſadvantage of being eaſily melted and flattened, if the heat be in the ſmalleſt degree raiſed too high; and porcelain is moſtly full of ſmall minute pores, through which the gas eſcapes, eſpecially when compreſſed by a column of water. For theſe reaſons I procured a tube of braſs, which Mr de la Briche got caſt and bored out of the ſolid for me at Straſburg, under his own inſpection. This tube is extremely convenient for decompoſing alcohol, which reſolves into carbon, carbonic acid gas, and hydrogen gas; it may likewiſe be uſed with the ſame advantage for decompoſing water by means of charcoal, and in a great number of experiments of this nature.

CHAP. VII.

Of the Composition and Application of Lutes.

THE neceffity of properly fecuring the junctures of chemical veffels, to prevent the efcape of any of the products of experiments, muft be fufficiently apparent; for this purpofe lutes are employed, which ought to be of fuch a nature as to be equally impenetrable to the moft fubtle fubftances as glafs itfelf, through which only caloric can efcape.

This firft object of lutes is very well accomplifhed by bees wax, melted with about an eighth part of turpentine. This lute is very eafily managed, fticks very clofely to glafs, and is very difficultly penetrable; it may be rendered more confiftent, and lefs or more hard or pliable by adding different kinds of refinous matters. Though this fpecies of lute anfwers extremely well for retaining gafes and vapours, there are many chemical experiments which produce confiderable heat, by which this lute becomes liquefied, and confequently the expanfive vapours muft very readily force through and efcape.

For

For ſuch caſes, the following fat lute is the beſt hitherto diſcovered, though not without its diſadvantages, which ſhall be pointed out. Take very pure and dry unbaked clay, reduced to a fine powder; put this into a braſs mortar, and beat it for ſeveral hours with a heavy iron peſtle, dropping in ſlowly ſome boiled lintſeed oil; this is oil which has been oxygenated, and has acquired a drying quality, by being boiled with litharge. This lute is more tenacious, and applies better, if amber varniſh be uſed inſtead of the above oil. To make this varniſh, melt ſome yellow amber in an iron-laddle, by which operation it loſes a part of its ſuccinic acid, and eſſential oil, and mix it with lintſeed oil. Though the lute prepared with this varniſh is better than that made with boiled oil, yet, as its additional expence is hardly compenſated by its ſuperior quality, it is ſeldom uſed.

The above fat lute is capable of ſuſtaining a very violent degree of heat, is impenetrable by acids and ſpiritous liquors, and adheres exceedingly well to metals, ſtone-ware, or glaſs, providing they have been previouſly rendered perfectly dry. But if, unfortunately, any of the liquor in the courſe of an experiment gets through, either between the glaſs and the lute, or between the layers of the lute itſelf, ſo as to moiſten the part, it is extremely difficult to cloſe

the opening. This is the chief inconvenience which attends the uſe of fat lute, and perhaps the only one it is ſubject to. As it is apt to ſoften by heat, we muſt ſurround all the junctures with ſlips of wet bladder applied over the luting, and fixed on by pack-thread tied round both above and below the joint; the bladder, and conſequently the lute below, muſt be farther ſecured by a number of turns of pack-thread all over it. By theſe precautions, we are free from every danger of accident; and the junctures ſecured in this manner may be conſidered, in experiments, as hermetically ſealed.

It frequently happens, that the figure of the junctures prevents the application of ligatures, which is the caſe with the three-necked bottles formerly deſcribed; and it even requires great addreſs to apply the twine without ſhaking the apparatus; ſo that, where a number of junctures require luting, we are apt to diſplace ſeveral while ſecuring one. In theſe caſes, we may ſubſtitute ſlips of linen, ſpread with white of egg and lime mixed together, inſtead of the wet bladder. Theſe are applied while ſtill moiſt, and very ſpeedily dry and acquire conſiderable hardneſs. Strong glue diſſolved in water may anſwer inſtead of white of egg. Theſe fillets are uſefully applied likewiſe over junctures luted together with wax and roſin.

Before

Before applying a lute, all the junctures of the vessels must be accurately and firmly fitted to each other, so as not to admit of being moved. If the beak of a retort is to be luted to the neck of a recipient, they ought to fit pretty accurately; otherwise we must fix them by introducing short pieces of soft wood, or of cork. If the disproportion between the two be very considerable, we must employ a cork which fits the neck of the recipient, having a circular hole of proper dimensions to admit the beak of the retort. The same precaution is necessary in adapting bent tubes to the necks of bottles in the apparatus represented Pl. IV. Fig. 1. and others of a similar nature. Each mouth of each bottle must be fitted with a cork, having a hole made with a round file of a proper size for containing the tube. And, when one mouth is intended to admit two or more tubes, which frequently happens when we have not a sufficient number of bottles with two or three necks, we must use a cork with two or three holes, Pl. IV. Fig. 8.

When the whole apparatus is thus solidly joined, so that no part can play upon another, we begin to lute. The lute is softened by kneading and rolling it between the fingers, with the assistance of heat, if necessary. It is rolled into little cylindrical pieces, and applied to the junctures, taking great care to make it

apply cloſe, and adhere firmly, in every part; a ſecond roll is applied over the firſt, ſo as to paſs it on each ſide, and ſo on till each juncture be ſufficiently covered; after this, the ſlips of bladder, or of linen, as above directed, muſt be carefully applied over all. Though this operation may appear extremely ſimple, yet it requires peculiar delicacy and management; great care muſt be taken not to diſturb one juncture whilſt luting another, and more eſpecially when applying the fillets and ligatures.

Before beginning any experiment, the cloſeneſs of the luting ought always to be previouſly tried, either by ſlightly heating the retort A, Pl. IV. Fig. 1. or by blowing in a little air by ſome of the perpendicular tubes *S s s s*; the alteration of preſſure cauſes a change in the level of the liquid in theſe tubes. If the apparatus be accurately luted, this alteration of level will be permanent; whereas, if there be the ſmalleſt opening in any of the junctures, the liquid will very ſoon recover its former level. It muſt always be remembered, that the whole ſucceſs of experiments in modern chemiſtry depends upon the exactneſs of this operation, which therefore requires the utmoſt patience, and moſt attentive accuracy.

It would be of infinite ſervice to enable chemiſts, eſpecially thoſe who are engaged in pneumatic proceſſes, to diſpenſe with the uſe of lutes,

or

or at leaſt to diminiſh the number neceſſary in complicated inſtruments. I once thought of having my apparatus conſtructed ſo as to unite in all its parts by fitting with emery, in the way of bottles with cryſtal-ſtoppers; but the execution of this plan was extremely difficult. I have ſince thought it preferable to ſubſtitute columns of a few lines of mercury in place of lutes, and have got an apparatus conſtructed upon this principle, which appears capable of very convenient application in a great number of circumſtances.

It conſiſts of a double-necked bottle A, Pl. XII. Fig. 12.; the interior neck *b c* communicates with the inſide of the bottle, and the exterior neck or rim *d e* leaves an interval between the two necks, forming a deep gutter intended to contain the mercury. The cap or lid of glaſs B enters this gutter and is properly fitted to it, having notches in its lower edge for the paſſage of the tubes which convey the gas. Theſe tubes, inſtead of entering directly into the bottles as in the ordinary apparatus, have a double bend for making them enter the gutter, as repreſented in Fig. 13. and for making them fit the notches of the cap B; they riſe again from the gutter to enter the inſide of the bottle over the border of the inner mouth. When the tubes are diſpoſed in their proper places, and the cap firmly fitted on, the gutter is filled with mercury,

mercury, by which means the bottle is completely excluded from any communication, excepting through the tubes. This apparatus may be very convenient in many operations in which the ſubſtances employed have no action upon mercury. Pl. XII. Fig. 14. repreſents an apparatus upon this principle properly fitted together.

Mr Seguin, to whoſe active and intelligent aſſiſtance I have been very frequently much indebted, has beſpoken for me, at the glaſs-houſes, ſome retorts hermetically united to their recipients, by which luting will be altogether unneceſſary.

CHAP.

CHAP. VIII.

Of Operations upon Combuſtion and Deflagration.

SECT. I.

Of Combuſtion in General.

COMBUSTION, according to what has been already ſaid in the Firſt Part of this Work, is the decompoſition of oxygen gas produced by a combuſtible body. The oxygen which forms the baſe of this gas is abſorbed by, and enters into combination with, the burning body, while the caloric and light are ſet free. Every combuſtion, therefore, neceſſarily ſuppoſes oxygenation; whereas, on the contrary, every oxygenation does not neceſſarily imply concomitant combuſtion; becauſe combuſtion, properly ſo called, cannot take place without diſengagement of caloric and light. Before combuſtion can take place, it is neceſſary that the baſe of oxygen gas ſhould have greater affinity

nity to the combuſtible body than it has to caloric; and this elective attraction, to uſe Bergmans expreſſion, can only take place at a certain degree of temperature, which is different for each combuſtible ſubſtance; hence the neceſſity of giving a firſt motion or beginning to every combuſtion by the approach of a heated body. This neceſſity of heating any body we mean to burn depends upon certain conſiderations, which have not hitherto been attended to by any natural philoſopher, wherefore I ſhall enlarge a little upon the ſubject in this place.

Nature is at preſent in a ſtate of equilibrium, which cannot have been attained until all the ſpontaneous combuſtions or oxygenations poſſible in the ordinary degrees of temperature had taken place. Hence, no new combuſtions or oxygenations can happen without deſtroying this equilibrium, and raiſing the combuſtible ſubſtances to a ſuperior degree of temperature. To illuſtrate this abſtract view of the matter by example: Let us ſuppoſe the uſual temperature of the earth a little changed, and that it were raiſed only to the degree of boiling water; it is evident, that, in this caſe, phoſphorus, which is combuſtible in a conſiderably lower degree of temperature, would no longer exiſt in nature in its pure and ſimple ſtate, but would always be procured in its acid or oxygenated ſtate, and its radical would become one of the ſubſtances un-

known

known to chemiſtry. By gradually increaſing the temperature of the earth the ſame circumſtance would ſucceſſively happen to all the bodies capable of combuſtion; and, at laſt, every poſſible combuſtion having taken place, there would no longer exiſt any combuſtible body whatever, as every ſubſtance ſuſceptible of that operation would be oxygenated, and conſequently incombuſtible.

There cannot therefore exiſt, ſo far as relates to us, any combuſtible body, except ſuch as are incombuſtible in the ordinary temperatures of the earth; or, what is the ſame thing, in other words, that it is eſſential to the nature of every combuſtible body, not to poſſeſs the property of combuſtion, unleſs heated, or raiſed to the degree of temperature at which its combuſtion naturally takes place. When this degree is once produced, combuſtion commences, and the caloric which is diſengaged by the decompoſition of the oxygen gas, keeps up the temperature neceſſary for continuing combuſtion. When this is not the caſe, that is, when the diſengaged caloric is inſufficient for keeping up the neceſſary temperature, the combuſtion ceaſes: This circumſtance is expreſſed in common language by ſaying, that a body burns ill, or with difficulty.

Although combuſtion poſſeſſes ſome circumſtances in common with diſtillation, eſpecially

with

with the compound kind of that operation, they differ in a very material point. In diſtillation there is a ſeparation of one part of the elements of the ſubſtance from each other, and a conſequent combination of theſe, in a new order, occaſioned by the affinities which take place in the increaſed temperature produced during diſtillation: This likewiſe happens in combuſtion, but with this farther circumſtance, that a new element, not originally in the body, is brought into action; oxygen is added to the ſubſtance ſubmitted to the operation, and caloric is diſengaged.

The neceſſity of employing oxygen in the ſtate of gas in all experiments with combuſtion, and the rigorous determination of the quantities employed, render this kind of operations peculiarly troubleſome. As almoſt all the products of combuſtion are diſengaged in the ſtate of gas, it is ſtill more difficult to retain them than even thoſe furniſhed during compound diſtillation; hence this precaution was entirely neglected by the ancient chemiſts; and this ſet of experiments excluſively belongs to modern chemiſtry.

Having thus pointed out, in a general way, the objects to be had in view in experiments upon combuſtion, I proceed, in the following ſections of this chapter, to deſcribe the different inſtruments I have uſed with this view. The following arrangement is formed, not upon the

nature

nature of the combuſtible bodies, but upon that of the inſtruments neceſſary for combuſtion.

SECT. II.

Of the Combuſtion of Phoſphorus.

In theſe combuſtions we begin by filling a jar, capable at leaſt of holding ſix pints, with oxygen gas in the water apparatus, Pl. V. Fig. 1.; when it is perfectly full, ſo that the gas begins to flow out below, the jar A is carried to the mercury apparatus, Pl. IV. Fig. 3. We then dry the ſurface of the mercury, both within and without the jar, by means of blotting-paper, taking care to keep the paper for ſome time entirely immerſed in the mercury before it is introduced under the jar, leſt we let in any common air, which ſticks very obſtinately to the ſurface of the paper. The body to be ſubmitted to combuſtion, being firſt very accurately weighed in nice ſcales, is placed in a ſmall flat ſhallow diſh, D, of iron or porcelain; this is covered by the larger cup P, which ſerves the office of a diving-bell, and the whole is paſſed through the mercury into the jar, after which the larger cup is retired. The difficulty of paſſing the materials of combuſtion in this manner through

through the mercury may be avoided by raiſing one of the ſides of the jar A, for a moment, and ſlipping in the little cup D, with the combuſtible body, as quickly as poſſible. In this manner of operating, a ſmall quantity of common air gets into the jar, but it is ſo very inconſiderable as not to injure either the progreſs or accuracy of the experiment in any ſenſible degree.

When the cup, D, is introduced under the jar, we ſuck out a part of the oxygen gas, ſo as to raiſe the mercury to E F, as formerly directed, Part I. Chap. V. otherwiſe when the combuſtible body is ſet on fire, the gas becoming dilated would be in part forced out, and we ſhould no longer be able to make any accurate calculation of the quantities before and after the experiment. A very convenient mode of drawing out the air is by means of an air-pump ſyringe adapted to the ſyphon, G H I, by which the mercury may be raiſed to any degree under twenty-eight inches. Very inflammable bodies, as phoſphorus, are ſet on fire by means of the crooked iron-wire, M N, Pl. IV. Fig. 16. made red-hot, and paſſed quickly through the mercury. Such as are leſs eaſily ſet on fire have a ſmall portion of tinder, upon which a minute particle of phoſphorus is fixed, laid upon them before uſing the red-hot iron.

In

In the firſt moment of combuſtion, the air, being heated, rarefies, and the mercury deſcends; but when, as in combuſtions of phoſphorus and iron, no elaſtic fluid is formed, abſorption becomes preſently very ſenſible, and the mercury riſes high into the jar. Great attention muſt be uſed not to burn too large a quantity of any ſubſtance in a given quantity of gas, otherwiſe, towards the end of the experiment, the cup would approach ſo near the top of the jar as to endanger breaking it, by the great heat produced, and the ſudden refrigeration from the cold mercury. For the methods of meaſuring the volume of the gaſes, and for correcting the meaſures according to the height of the barometer and thermometer, &c. ſee Chap. II. Sect. V. and VI. of this Part.

The above proceſs anſwers very well for burning all the concrete ſubſtances, and even for the fixed oils: Theſe laſt are burned in lamps under the jar, and are readily ſet on fire by means of tinder, phoſphorus, and hot iron. But it is dangerous for ſubſtances ſuſceptible of evaporating in a moderate heat, ſuch as ether, alcohol, and the eſſential oils; theſe ſubſtances diſſolve in conſiderable quantity in oxygen gas; and, when ſet on fire, a dangerous and ſudden exploſion takes place, which forces up the jar to a great height, and daſhes it in a thouſand pieces. From the effects of two ſuch exploſions, ſome of the mem-

bers of the Academy and myſelf eſcaped very narrowly. Beſides, though this manner of operating is ſufficient for determining pretty accurately the quantity of oxygen gas abſorbed, and of carbonic acid produced, yet as water is likewiſe formed in all experiments upon vegetable and animal matters which contain an exceſs of hydrogen, this apparatus can neither collect it, nor determine its quantity. The experiment with phoſphorus is even incomplete in this way, as it is impoſſible to demonſtrate that the weight of the phoſphoric acid produced is equal to the ſum of the weights of the phoſphorus burnt and of oxygen gas abſorbed during the proceſs: I have been, therefore, obliged to vary the inſtruments according to circumſtances, and to employ ſeveral of different kinds, which I ſhall deſcribe in their order, beginning with that uſed for burning phoſphorus.

Take a large balloon A, Pl. IV. Fig. 4. of cryſtal or white glaſs, with an opening EF, about two inches and a half, or three inches, diameter, to which a cap of braſs is accurately fitted with emery, and which has two holes for the paſſage of the tubes *x x x*, *y y y*. Before ſhutting the balloon with its cover, place within it the ſtand, BC, ſupporting the cup of porcelain, D, which contains the phoſphorus. Then lute on the cap with fat lute, and allow it to dry for ſome days, and weigh the whole accurately; after

after this exhauſt the balloon by means of an air-pump connected with the tube *x x x*, and fill it with oxygen gas by the tube *y y y*, from the gazometer, Pl. VIII. Fig. 1. deſcribed Chap. II. Sect. II. of this part. The Phoſphorus is then ſet on fire by means of a burning-glaſs, and is allowed to burn till the cloud of concrete phoſphoric acid ſtops the combuſtion, oxygen gas being continually ſupplied from the gazometer. When the apparatus has cooled, it is weighed and unluted; the tare of the inſtrument being allowed, the weight is that of the phoſphoric acid contained. It is proper, for greater accuracy, to examine the air or gas contained in the balloon after combuſtion, as it may happen to be ſomewhat heavier or lighter than common air; and this difference of weight muſt be taken into account in the calculations upon the reſults of the experiment.

SECT. III.

Of the Combuſtion of Charcoal.

The apparatus I have employed for this proceſs conſiſts of a ſmall conical furnace of hammered copper, repreſented in perſpective, Pl. XII. Fig. 9. and internally diſplayed Fig. 11. It is

 divided

divided into the furnace, ABC, where the charcoal is burnt, the grate, *d e*, and the aſh-hole, F; the tube, GH, in the middle of the dome of the furnace, ſerves to introduce the charcoal, and as a chimney for carrying off the air which has ſerved for combuſtion. Through the tube *l m n*, which communicates with the gazometer, the oxygen gas, or air, intended for ſupporting the combuſtion, is conveyed into the aſh-hole, F, whence it is forced, by the application of preſſure to the gazometer, to paſs through the grate, *d e*, and to blow upon the burning charcoal placed immediately above.

Oxygen gas, which forms $\frac{28}{100}$ parts of atmoſpheric air, is changed into carbonic acid gas during combuſtion with charcoal, while the azotic gas of the air is not at all altered. Hence, after the combuſtion of charcoal in atmoſpheric air, a mixture of carbonic acid gas and azotic gas muſt remain; to allow this mixture to paſs off, the tube, *o p*, is adapted to the chimney, GH, by means of a ſcrew at G, and conveys the gas into bottles half filled with ſolution of cauſtic potaſh. The carbonic acid gas is abſorbed by the alkali, and the azotic gas is conveyed into a ſecond gazometer, where its quantity is aſcertained.

The weight of the furnace, ABC, is firſt accurately determined; then the tube RS, Fig. 10. of known weight, is introduced by the chimney,

ney, GH, till its lower end S, refts upon the grate, *d e*, which it occupies entirely; in the next place, the furnace is filled with charcoal, and the whole is weighed again, to know the exact quantity of charcoal fubmitted to experiment. The furnace is now put in its place, the tube, *l m n*, is fcrewed to that which communicates with the gazometer, and the tube, *o p*, to that which communicates with the bottles of alkaline folution. Every thing being in readinefs, the ftop-cock of the gazometer is opened, a fmall piece of burning charcoal is thrown into the tube, RS, which is inftantly withdrawn, and the tube, *o p*, is fcrewed to the chimney, GH. The little piece of burning charcoal falls upon the grate, and in this manner gets below the whole charcoal, and is kept on fire by the ftream of air from the gazometer. To be certain that the combuftion is begun, and that it goes on properly, the tube, *q r s*, is fixed to the furnace, having a piece of glafs cemented to its upper extremity, *s*, through which we can fee if the charcoal be on fire.

I neglected to obferve above, that the furnace, and its appendages, are plunged into water in the ciftern, TVXY, Fig. 11. Pl. XII. to which ice may be added to moderate the heat, if neceffary; though the heat is by no means very confiderable, as there is no air fupplied but what comes from the gazometer, and no more of the charcoal

burns at one time than what is immediately over the grate.

As one piece of charcoal is consumed, another falls down into its place, in consequence of the declivity of the fides of the furnace; this gets into the ftream of air, from the grate, *d e*, and is burnt; and fo on, fucceffively, till the whole charcoal is confumed. The air which has ferved the purpofe of the combuftion paffes through the mafs of charcoal, and is forced, by the preffure of the gazometer, to efcape through the tube, *o p*, and to pafs through the bottles of alkaline folution.

This experiment furnifhes all the neceffary data for a complete analyfis of atmofpheric air and of charcoal. We know the weight of charcoal confumed; the gazometer gives us the meafure of the air employed; the quantity and quality of gas remaining after combuftion may be determined, as it is received, either in another gazometer, or in jars, in a pneumato-chemical apparatus; the weight of afhes remaining in the afh-hole is readily afcertained: and finally, the additional weight acquired by the bottles of alkaline folution gives the exact quantity of carbonic acid formed during the procefs. By this experiment we may likewife determine, with fufficient accuracy, the proportions in which carbon and oxygen enter into the compofition of carbonic acid.

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In a future memoir I ſhall give an account to the Academy of a ſeries of experiments I have undertaken, with this inſtrument, upon all the vegetable and animal charcoals. By ſome very ſlight alterations, this machine may be made to anſwer for obſerving the principal phenomena of reſpiration.

SECT. IV.

Of the Combuſtion of Oils.

Oils are more compound in their nature than charcoal, being formed by the combination of at leaſt two elements, carbon and hydrogen; of courſe, after their combuſtion in common air, water, carbonic acid gas, and azotic gas remain. Hence the apparatus employed for their combuſtion requires to be adapted for collecting theſe three products, and is conſequently more complicated than the charcoal furnace.

The apparatus I employ for this purpoſe is compoſed of a large jar or pitcher A, Pl. XII. Fig. 4. ſurrounded at its upper edge by a rim of iron properly cemented at DE, and receding from the jar at BC, ſo as to leave a furrow or gutter *xx*, between it and the outſide of the jar

 ſomewhat

ſomewhat more than two inches deep. The cover or lid of the jar, Fig 5. is likewiſe ſurrounded by an iron-rim *f g*, which adjuſts into the gutter *x x*, Fig. 4. which being filled with mercury, has the effect of cloſing the jar hermetically in an inſtant, without uſing any lute; and, as the gutter will hold about two inches of mercury, the air in the jar may be made to ſuſtain the preſſure of more than two feet of water, without danger of its eſcaping.

The lid has four holes, T *h i k*, for the paſſage of an equal number of tubes. The opening T is furniſhed with a leather-box, through which paſſes the rod, Fig. 3. intended for raiſing and lowering the wick of the lamp, as will be afterwards directed. The three other holes are intended for the paſſage of three ſeveral tubes; one of theſe conveys the oil to the lamp, a ſecond conveys air for keeping up the combuſtion, and the third carries off the air, after it has ſerved for combuſtion. The lamp in which the oil is burnt is repreſented Fig. 2.; *a* is the reſervoir of oil, having a funnel by which it is filled; *b c d e f g h* is a ſyphon which conveys the oil to the lamp 11; 7, 8, 9, 10, is the tube which conveys the air for combuſtion from the gazometer to the ſame lamp. The tube *b c* is formed externally, at its lower end *b*, into a male ſcrew, which turns in a female ſcrew in the lid of the reſervoir of oil *a*; ſo that, by turning the

the reſervoir one way or the other, it is made to riſe or fall, by which the oil is kept at the neceſſary level.

When the ſyphon is to be filled, and the communication formed between the reſervoir of oil and the lamp, the ſtop-cock *c* is ſhut, and that at *e* opened; oil is then poured in by the opening *f* at the top of the ſyphon, till it riſes within three or four lines of the upper edge of the lamp, after which the ſtop-cock *k* is ſhut, and that at *c* opened; the oil is next poured in at *f*, till the branch *b c d* of the ſyphon is filled, and then the ſtop-cock *e* is cloſed. The two branches of the ſyphon being now completely filled, a communication is fully eſtabliſhed between the reſervoir and the lamp.

In Pl. XII. Fig. 1. all the parts of the lamp 11, Fig. 2. are repreſented magnified, to ſhew them diſtinctly. The tube *i k* carries the oil from the reſervoir to the cavity *a a a a*, which contains the wick; the tube 9, 10, brings the air from the gazometer for keeping up the combuſtion; this air ſpreads through the cavity *d d d d*, and, by means of the paſſages *c c c c* and *b b b b* is diſtributed on each ſide of the wick, after the principles of the lamps conſtructed by Argand, Quinquet, and Lange.

To render the whole of this complicated apparatus more eaſily underſtood, and that its deſcription may make all others of the ſame kind more

more readily followed, it is reprefented, completely connected together for ufe, in Pl. XI. The gazometer P furnifhes air for the combuftion, by the tube and ftop-cock 1, 2; the tube 2, 3, communicates with a fecond gazometer, which is filled while the firft one is emptying during the procefs, that there may be no interruption to the combuftion; 4, 5, is a tube of glafs filled with deliquefcent falts, for drying the air as much as poffible in its paffage; and the weight of this tube and its contained falts, at the beginning of the experiment, being known, it is eafy to determine the quantity of water abforbed by them from the air. From this deliquefcent tube, the air is conducted through the pipe 5, 6, 7, 8, 9, 10, to the lamp 11, where it fpreads on both fides of the wick, as before defcribed, and feeds the flame. One part of this air, which ferves to keep up the combuftion of the oil, forms carbonic acid gas and water, by oxygenating its elements. Part of this water condenfes upon the fides of the pitcher A, and another part is held in folution in the air, by means of caloric furnifhed during the combuftion. This air is forced by the compreffion of the gazometer to pafs through the tube 12, 13, 14, 15, into the bottle 16, and the worm 17, 18, where the water is fully condenfed from the refrigeration of the air; and, if any water ftill remain

main in ſolution, it is abſorbed by deliqueſcent ſalts contained in the tube 19, 20.

All theſe precautions are ſolely intended for collecting and determining the quantity of water formed during the experiment; the carbonic acid and azotic gas remain to be aſcertained. The former is abſorbed by cauſtic alkaline ſolution in the bottles 22 and 25. I have only repreſented two of theſe in the figure, but nine at leaſt are requiſite; and the laſt of the ſeries may be half filled with lime-water, which is the moſt certain reagent for indicating the preſence of carbonic acid; if the lime-water is not rendered turbid, we may be certain that no ſenſible quantity of that acid remains in the air.

The reſt of the air which has ſerved for combuſtion, and which chiefly conſiſts of azotic gas, though ſtill mixed with a conſiderable portion of oxygen gas, which has eſcaped unchanged from the combuſtion, is carried through a third tube 28, 29, of deliqueſcent ſalts, to deprive it of any moiſture it may have acquired in the bottles of alkaline ſolution and lime-water, and from thence by the tube 29, 30, into a gazometer, where its quantity is aſcertained. Small eſſays are then taken from it, which are expoſed to a ſolution of ſulphuret of potaſh, to aſcertain the proportions of oxygen and azotic gas it contains.

In the combuſtion of oils, the wick becomes

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at laſt charred, and obſtructs the riſe of the oil; beſides, if we raiſe the wick above a certain height, more oil riſes through its capillary tubes than the ſtream of air is capable of conſuming, and ſmoke is produced. Hence it is neceſſary to be able to lengthen or ſhorten the wick without opening the apparatus; this is accompliſhed by means of the rod 31, 32, 33, 34, which paſſes through a leather-box, and is connected with the ſupport of the wick; and that the motion of this rod, and conſequently of the wick, may be regulated with the utmoſt ſmoothneſs and facility, it is moved at pleaſure by a pinion which plays in a toothed rack. The rod, with its appendages, are repreſented Pl. XII. Fig. 3. It appeared to me, that the combuſtion would be aſſiſted by ſurrounding the flame of the lamp with a ſmall glaſs-jar open at both ends, as repreſented in its place in Pl. XI.

I ſhall not enter into a more detailed deſcription of the conſtruction of this apparatus, which is ſtill capable of being altered and modified in many reſpects; but ſhall only add, that when it is to be uſed in experiment, the lamp and reſervoir with the contained oil muſt be accurately weighed, after which it is placed as before directed, and lighted; having then formed the connection between the air in the gazometer and the lamp, the external jar A, Pl. XI. is fixed over all, and ſecured by means of the board

BC,

BC, and by two rods of iron which connect this board with the lid, and are ſcrewed to it. A ſmall quantity of oil is burnt while the jar is adjuſting to the lid, and the product of that combuſtion is loſt; there is likewiſe a ſmall portion of air from the gazometer loſt at the ſame time. Both of theſe are of very inconſiderable conſequence in extenſive experiments, and they are even capable of being valued in our calculation of the reſults.

In a particular memoir, I ſhall give an account to the Academy of the difficulties inſeparable from this kind of experiments: Theſe are ſo inſurmountable and troubleſome, that I have not hitherto been able to obtain any rigorous determination of the quantities of the products. I have ſufficient proof, however, that the fixed oils are entirely reſolved during combuſtion into water and carbonic acid gas, and conſequently that they are compoſed of hydrogen and carbon; but I have no certain knowledge reſpecting the proportions of theſe ingredients.

SECT. V.

Of the Combustion of Alcohol.

The combustion of alcohol may be very readily performed in the apparatus already described for the combustion of charcoal and phosphorus. A lamp filled with alcohol is placed under the jar A, Pl. IV. Fig. 3. a small morsel of phosphorus is placed upon the wick of the lamp, which is set on fire by means of the hot iron, as before directed. This process is, however, liable to considerable inconveniency; it is dangerous to make use of oxygen gas at the beginning of the experiment for fear of deflagration, which is even liable to happen when common air is employed. An accident of this kind had very near proved fatal to myself, in presence of some members of the Academy. Instead of preparing the experiment, as usual, at the time it was to be performed, I had disposed every thing in order the evening before; the atmospheric air of the jar had thereby sufficient time to dissolve a good deal of the alcohol, and this evaporation had even been considerably promoted by the height of the column of mercury, which I had raised to EF, Pl. IV. Fig. 3. The moment I attempted

ed to ſet the little morſel of phoſphorus on fire by means of the red hot iron, a violent exploſion took place, which threw the jar with great violence againſt the floor of the laboratory, and daſhed it in a thouſand pieces.

Hence we can only operate upon very ſmall quantities, ſuch as ten or twelve grains of alcohol, in this manner; and the errors which may be committed in experiments upon ſuch ſmall quantities prevent our placing any confidence in their reſults. I endeavoured to prolong the combuſtion, in the experiments contained in the Memoirs of the Academy for 1784, p. 593. by lighting the alcohol firſt in common air, and furniſhing oxygen gas afterwards to the jar, in proportion as it conſumed; but the carbonic acid gas produced by the proceſs became a great hinderance to the combuſtion, the more ſo that alcohol is but difficultly combuſtible, eſpecially in worſe than common air; ſo that even in this way very ſmall quantities only could be burnt.

Perhaps this combuſtion might ſucceed better in the oil apparatus, Pl. XI.; but I have not hitherto ventured to try it. The jar A in which the combuſtion is performed, is near 1400 cubical inches in dimenſion; and, were an exploſion to take place in ſuch a veſſel, its conſequences would be very terrible, and very difficult to guard againſt. I have not, however, deſpaired of making the attempt.

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In consequence of these difficulties, I have been hitherto obliged to confine myself to experiments upon very small quantities of alcohol, at least to combustions made in open vessels, such as that represented in Pl. IX. Fig. 5. which will be described in Section VII. of this Chapter. If I am ever able to remove these difficulties, I shall resume this investigation.

SECT. VI.

Of the Combustion of Ether.

Though the combustion of ether in close vessels does not present the same difficulties as that of alcohol, yet it involves some of a different kind, not more easily overcome, and which still prevent the progress of my experiments. I endeavoured to profit by the property which ether possesses of dissolving in atmospheric air, and being thereby rendered inflammable without explosion. For this purpose, I constructed the reservoir of ether *a b c d*, Pl. XII. Fig. 8. to which air is brought from the gazometer by the tube 1, 2, 3, 4. This air spreads, in the first place, in the double lid *a c* of the reservoir, from which it passes through seven tubes *ef*, *gh*, *ik*, &c. which descend to the bottom of the ether, and it is forced

forced, by the preſſure of the gazometer, to boil up through the ether in the reſervoir. We may replace the ether in this firſt reſervoir, in proportion as it is diſſolved and carried off by the air, by means of the ſupplementary reſervoir E, connected by a braſs tube fifteen or eighteen inches long, and ſhut by a ſtop-cock. This length of the connecting tube is to enable the deſcending ether to overcome the reſiſtance, occaſioned by the preſſure of the air from the gazometer.

The air, thus loaded with vapours of ether, is conducted by the tube 5, 6, 7, 8, 9, to the jar A, into which it is allowed to eſcape through a capillary opening, at the extremity of which it is ſet on fire. The air, when it has ſerved the purpoſe of combuſtion, paſſes through the bottle 16, Pl. XI. the worm 17, 18, and the deliqueſcent tube 19, 20, after which it paſſes through the alkaline bottles; in theſe its carbonic acid gas is abſorbed, the water formed during the experiment having been previouſly depoſited in the former parts of the apparatus.

When I cauſed conſtruct this apparatus, I ſuppoſed that the combination of atmoſpheric air and ether formed in the reſervoir *a b c d*, Pl. XII. Fig. 8. was in proper proportion for ſupporting combuſtion; but in this I was miſtaken; for there is a very conſiderable quantity of exceſs of ether; ſo that an additional quantity of atmo-

ſpheric air is neceſſary to enable it to burn fully. Hence a lamp conſtructed upon theſe principles will burn in the open air, which furniſhes the quantity of oxygen neceſſary for combuſtion, but will not burn in cloſe veſſels in which the air is not renewed. Owing to this circumſtance, my ether lamp went out ſoon after being lighted and ſhut up in the jar A, Pl. XII. Fig. 8. To remedy this defect, I endeavoured to bring atmoſpheric air to the lamp by the lateral tube 10, 11, 12, 13, 14, 15, which I diſtributed circularly round the flame; but the flame is ſo exceedingly rare, that it is blown out by the gentleſt poſſible ſtream of air, ſo that I have not hitherto ſucceeded in burning ether. I do not, however, deſpair of being able to accompliſh it by means of ſome changes I am about to have made upon this apparatus.

SECT. VII.

Of the Combuſtion of Hydrogen Gas, and the Formation of Water.

In the formation of water, two ſubſtances, hydrogen and oxygen, which are both in the aëriform ſtate before combuſtion, are transformed into a liquid, or water, by the operation.

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This experiment would be very eaſy, and would only require very ſimple inſtruments, if it were poſſible to procure the two gaſes perfectly pure, ſo that they might burn without any reſiduum. We might, in that caſe, operate in very ſmall veſſels, and, by continually furniſhing the two gaſes in proper proportions, might continue the combuſtion indefinitely. But, hitherto, chemiſts have only employed impure oxygen gas, mixed with azotic gas; from which circumſtance they have only been able to keep up the combuſtion of hydrogen gas for a very limited time in cloſe veſſels, becauſe, as the reſiduum of azotic gas is continually increaſing, the air becomes at laſt ſo much contaminated, that the flame weakens and goes out. This inconvenience is ſo much the greater in proportion as the oxygen gas employed is leſs pure. From this circumſtance, we muſt either be ſatisfied with operating upon ſmall quantities, or muſt exhauſt the veſſels at intervals, to get rid of the reſiduum of azotic gas; but, in this caſe, a portion of the water formed during the experiment is evaporated by the exhauſtion; and the reſulting error is the more dangerous to the accuracy of the proceſs, that we have no certain means of aſcertaining its value.

Theſe conſiderations make me deſirous to repeat the principal experiments of pneumatic chemiſtry with oxygen gas entirely free from

any admixture of azotic gas; and this may be procured from oxygenated muriat of potash. The oxygen gas extracted from this salt does not appear to contain azot, unless accidentally; so that by proper precautions, it may be obtained perfectly pure. In the mean time, the apparatus employed by Mr Meusnier and me for the combustion of hydrogen gas, which is described in the experiment for recomposition of water, Part I. Chap. VIII. and need not therefore be here repeated, will answer the purpose; when pure gases are procured, this apparatus will require no alterations, except that the capacity of the vessels may then be diminished. See Pl. IV. Fig. 5.

The combustion, when once begun, continues for a considerable time, but weakens gradually, in proportion as the quantity of azotic gas, remaining from the combustion, increases, till at last the azotic gas is in such over proportion that the combustion can no longer be supported, and the flame goes out. This spontaneous extinction must be prevented, because, as the hydrogen gas is pressed upon in its reservoir, by an inch and a half of water, while the oxygen gas suffers a pressure only of three lines, a mixture of the two would take place in the balloon, which would at last be forced, by the superior pressure, into the reservoir of oxygen gas: Wherefore the combustion must be stop-

ped,

ped, by ſhutting the ſtop-cock of the tube *d* D*d* whenever the flame grows very feeble; for which purpoſe it muſt be attentively watched.

There is another apparatus for combuſtion, which, though we cannot with it perform experiments with the ſame ſcrupulous exactneſs as with the preceding inſtruments, gives very ſtriking reſults, that are extremely proper to be ſhewn in courſes of philoſophical chemiſtry. It conſiſts of a worm EF, Pl. IX. Fig. 5. contained in a metallic cooler ABCD. To the upper part of this worm E, the chimney GH is fixed, which is compoſed of two tubes, the inner of which is a continuation of the worm, and the outer one is a caſe of tin-plate, which ſurrounds it at about an inch diſtance, and the interval is filled up with ſand. At the inferior extremity K of the inner tube, a glaſs-tube is fixed, to which we adapt the Argand lamp LM for burning alcohol, &c.

Things being thus diſpoſed, and the lamp being filled with a determinate quantity of alcohol, it is ſet on fire; the water which is formed during the combuſtion riſes in the chimney KE, and being condenſed in the worm, runs out at its extremity F into the bottle P. The double tube of the chimney, filled with ſand in the interſtice, is to prevent the tube from cooling in its upper part, and condenſing the water; otherwiſe, it would fall back in the tube, and we ſhould not be able to aſcertain its quantity, and

befides it might fall in drops upon the wick, and extinguifh the flame. The intention of this conftruction, is to keep the chimney always hot, and the worm always cool, that the water may be preferved in the ftate of vapour while rifing, and may be condenfed immediately upon getting into the defcending part of the apparatus. By this inftrument, which was contrived by Mr Meufnier, and which is defcribed by me in the Memoirs of the Academy for 1784, p. 593. we may, with attention to keep the worm always cold, collect nearly feventeen ounces of water from the combuftion of fixteen ounces of alcohol.

SECT. VIII.

Of the Oxydation of Metals.

The term *oxydation*, or *calcination*, is chiefly ufed to fignify the procefs by which metals expofed to a certain degree of heat are converted into oxyds, by abforbing oxygen from the air. This combination takes place in confequence of oxygen poffeffing a greater affinity to metals, at a certain temperature, than to caloric, which becomes

becomes difengaged in its free ftate; but, as this difengagement, when made in common air, is flow and progreffive, it is fcarcely evident to the fenfes. It is quite otherwife, however, when oxydation takes place in oxygen gas; for, being produced with much greater rapidity, it is generally accompanied with heat and light, fo as evidently to fhew that metallic fubftances are real combuftible bodies.

All the metals have not the fame degree of affinity to oxygen. Gold, filver, and platina, for inftance, are incapable of taking it away from its combination with caloric, even in the greateft known heat; whereas the other metals abforb it in a larger or fmaller quantity, until the affinities of the metal to oxygen, and of the latter to caloric, are in exact equilibrium. Indeed, this ftate of equilibrium of affinities may be affumed as a general law of nature in all combinations.

In all operations of this nature, the oxydation of metals is accelerated by giving free accefs to the air; it is fometimes much affifted by joining the action of bellows, fo contrived as to direct a ftream of air over the furface of the metal. This procefs becomes greatly more rapid if a ft eam of oxygen gas be ufed, which is readily done by means of the gazometer formerly defcribed. The metal, in this cafe, throws out a brilliant flame, and the oxydation is very quickly accomplifhed;

 but

but this method can only be uſed in very confined experiments, on account of the expence of procuring oxygen-gas. In the eſſay of ores, and in all the common operations of the laboratory, the calcination or oxydation of metals is uſually performed in a diſh of baked clay, Pl. IV. Fig. 6. commonly called a *roaſting teſt*, placed in a ſtrong furnace. The ſubſtances to be oxydated are frequently ſtirred, on purpoſe to preſent freſh ſurfaces to the air.

Whenever this operation is performed upon a metal which is not volatile, and from which nothing flies off into the ſurrounding air during the proceſs, the metal acquires additional weight; but the cauſe of this increaſed weight during oxydation could never have been diſcovered by means of experiments performed in free air; and it is only ſince theſe operations have been performed in cloſe veſſels, and in determinate quantities of air, that any juſt conjectures have been formed concerning the cauſe of this phenomenon. The firſt method for this purpoſe is due to Dr Prieſtley, who expoſes the metal to be calcined in a porcelain cup N, Pl. IV. Fig. 11. placed upon the ſtand IK, under a jar A, in the baſon BCDE, full of water; the water is made to riſe up to GH, by ſucking out the air with a ſyphon, and the focus of a burning-glaſs is made to fall upon the metal. In a few minutes the oxydation

oxydation takes places, a part of the oxygen contained in the air combines with the metal, and a proportional diminution of the volume of air is produced; what remains is nothing more than azotic gas, ſtill however mixed with a ſmall quantity of oxygen gas. I have given an account of a ſeries of experiments made with this apparatus in my Phyſical and Chemical Eſſays, firſt publiſhed in 1773. Mercury may be uſed inſtead of water in this experiment, whereby the reſults are rendered ſtill more concluſive.

Another proceſs for this purpoſe was invented by Mr Boyle, and of which I gave an account in the Memoirs of the Academy for 1774, p. 351. The metal is introduced into a retort, Pl. III. Fig. 20. the beak of which is hermetically ſealed; the metal is then oxydated by means of heat applied with great precaution. The weight of the veſſel, and its contained ſubſtances, is not at all changed by this proceſs, until the extremity of the neck of the retort is broken; but, when that is done, the external air ruſhes in with a hiſſing noiſe. This operation is attended with danger, unleſs a part of the air is driven out of the retort, by means of heat, before it is hermetically ſealed, as otherwiſe the retort would be apt to burſt by the dilation of the air when placed in the furnace. The quantity of air driven out may be received under a jar in the pneumato-chemical apparatus,

tus, by which its quantity, and that of the air remaining in the retort, is aſcertained. I have not multiplied my experiments upon oxydation of metals ſo much as I could have wiſhed; neither have I obtained ſatisfactory reſults with any metal except tin. It is much to be wiſhed that ſome perſon would undertake a ſeries of experiments upon the oxydation of metals in the ſeveral gaſes; the ſubject is important, and would fully repay any trouble which this kind of experiment might occaſion.

As all the oxyds of mercury are capable of revivifying without addition, and reſtore the oxygen gas they had before abſorbed, this ſeemed to be the moſt proper metal for becoming the ſubject of concluſive experiments upon oxydation. I formerly endeavoured to accompliſh the oxydation of mercury in cloſe veſſels, by filling a retort, containing a ſmall quantity of mercury, with oxygen gas, and adapting a bladder half full of the ſame gas to its beak; See Pl. IV. Fig. 12. Afterwards, by heating the mercury in the retort for a very long time, I ſucceeded in oxydating a very ſmall portion, ſo as to form a little red oxyd floating upon the ſurface of the running mercury; but the quantity was ſo ſmall, that the ſmalleſt error committed in the determination of the quantities of oxygen gas before and after the operation, muſt have thrown very great uncertainty upon the

reſults

results of the experiment. I was, besides, dissatisfied with this process, and not without cause, lest any air might have escaped through the pores of the bladder, more especially as it becomes shrivelled by the heat of the furnace, unless covered over with cloths kept constantly wet.

This experiment is performed with more certainty in the apparatus described in the Memoirs of the Academy for 1775, p. 580. This consists of a retort, A, Pl. IV. Fig. 2. having a crooked glass-tube BCDE of ten or twelve lines internal diameter, melted on to its beak, and which is engaged under the bell-glass FG, standing with its mouth downwards, in a bason filled with water or mercury. The retort is placed upon the bars of the furnace MMNN, Pl. IV. Fig. 2. or in a sand-bath, and by means of this apparatus we may, in the course of several days, oxydate a small quantity of mercury in common air; the red oxyd floats upon the surface, from which it may be collected and revived, so as to compare the quantity of oxygen gas obtained in revivification with the absorption which took place during oxydation. This kind of experiment can only be performed upon a small scale, so that no very certain conclusions can be drawn from it *.

The

* See an account of this experiment, Part I. Chap. iii. —A.

The combuſtion of iron in oxygen gas being a true oxydation of that metal, ought to be mentioned in this place. The apparatus employed by Mr Ingenhouſz for this operation is repreſented in Pl. IV. Fig. 17.; but, having already deſcribed it ſufficiently in Chap. III., I ſhall refer the reader to what is ſaid of it in that place. Iron may likewiſe be oxydated by combuſtion in veſſels filled with oxygen gas, in the way already directed for phoſphorus and charcoal. This apparatus is repreſented Pl. IV. Fig. 3. and deſcribed in the fifth chapter of the firſt part of this work. We learn from Mr Ingenhouſz, that all the metals, except gold, ſilver, and mercury, may be burnt or oxydated in the ſame manner, by reducing them into very fine wire, or very thin plates cut into narrow ſlips; theſe are twiſted round with iron-wire, which communicates the property of burning to the other metals.

Mercury is even difficultly oxydated in free air. In chemical laboratories, this proceſs is uſually carried on in a matraſs A, Pl. IV. Fig. 10. having a very flat body, and a very long neck BC, which veſſel is commonly called *Boyles hell.* A quantity of mercury is introduced ſufficient to cover the bottom, and it is placed in a ſand-bath, which keeps up a conſtant heat approaching to that of boiling mercury. By continuing this operation with five or ſix ſimi-

lar.

lar matrasses during several months, and renewing the mercury from time to time, a few ounces of red oxyd are at last obtained. The great slowness and inconvenience of this apparatus arises from the air not being sufficiently renewed; but if, on the other hand, too free a circulation were given to the external air, it would carry off the mercury in solution in the state of vapour, so that in a few days none would remain in the vessel.

As, of all the experiments upon the oxydation of metals, those with mercury are the most conclusive, it were much to be wished that a simple apparatus could be contrived by which this oxydation and its results might be demonstrated in public courses of chemistry. This might, in my opinion, be accomplished by methods similar to those I have already described for the combustion of charcoal and the oils; but, owing to other pursuits, I have not been able hitherto to resume this kind of experiment.

The oxyd of mercury revives without addition, by being heated to a slightly red heat. In this degree of temperature, oxygen has greater affinity to caloric than to mercury, and forms oxygen gas. This is always mixed with a small portion of azotic gas, which indicates that the mercury absorbs a small portion of this latter gas during oxydation. It almost always contains a little carbonic acid gas, which must undoubtedly

doubtedly be attributed to the foulneſſes of the oxyd; theſe are charred by the heat, and convert a part of the oxygen gas into carbonic acid.

If chemiſts were reduced to the neceſſity of procuring all the oxygen gas, employed in their experiments, from mercury oxydated by heat without addition, or, as it is called, *calcined* or *precipitated* per ſe, the exceſſive dearneſs of that preparation would render experiments, even upon a moderate ſcale, quite impracticable. But mercury may likewiſe be oxydated by means of nitric acid; and in this way we procure a red oxyd, even more pure than that produced by calcination. I have ſometimes prepared this oxyd by diſſolving mercury in nitric acid, evaporating to dryneſs, and calcining the ſalt, either in a retort, or in capſules formed of pieces of broken matraſſes and retorts, in the manner formerly deſcribed; but I have never ſucceeded in making it equally beautiful with what is ſold by the druggiſts, and which is, I believe, brought from Holland. In chooſing this, we ought to prefer what is in ſolid lumps, compoſed of ſoft adhering ſcales, as when in powder it is ſometimes adulterated with red oxyd of lead.

To obtain oxygen gas from the red oxyd of mercury, I uſually employ a porcelain-retort, having a long glaſs-tube adapted to its beak, which

which is engaged under jars in the water pneumato-chemical apparatus; and I pla e a bottle in the water, at the end of the tube, for receiving the mercury, in proportion as it revives and diftils over. As the oxygen gas nev r appears till the retort becomes red, it feems to prove the principle eftablifhed by Mr Berthollet, that an obfcure heat can never form oxygen gas, and that light is one of its conftituent elements. We muft reject the firft portion of gas which comes over, as being mixed with common air, from what was contained in the retort at the beginning of the experiment; but, even with this precaution, the oxygen gas procured is ufually contaminated with a tenth part of azotic gas, and with a very fmall portion of carbonic acid gas. This latter is readily got rid of, by making the gas pafs through a folution of cauftic alkali, but we know of no method for feparating the azotic gas; its proportions may however be afcertained, by leaving a known quantity of the oxygen gas contaminated with it for a fortnight, in contact with fulphuret of foda or potafh, which abforbs the oxygen gas, and converts the fulphur into fulphuric acid, leaving the azotic gas pure.

We may likewife procure oxygen gas from black oxyd of manganefe, or from nitrat of potafh, by expofing them to a red heat, in the apparatus already defcribed for operating upon red oxyd of mercury; only, as it requires fuch a heat

heat as is at leaſt capable of ſoftening glaſs, we muſt employ retorts of ſtone or of porcelain. But the pureſt and beſt oxygen gas is what is diſengaged from oxygenated muriat of potaſh by ſimple heat. This operation is performed in a glaſs-retort, and the gas obtained is perfectly pure, provided that the firſt portions, which are mixed with the common air of the veſſels, be rejected.

CHAP.

CHAP. IX.

Of Deflagration.

I Have already ſhewn, Part I. Chapter IX. that oxygen does not always part with the whole of the caloric it contained in the ſtate of gas, when it enters into combination with other bodies. It carries almoſt the whole of its caloric along with it on entering into the combinations which form nitric acid and oxygenated muriatic acid; ſo that in nitrats, and more eſpecially in oxygenated muriats, the oxygen is, in a certain degree, in the ſtate of oxygen gas, condenſed, and reduced to the ſmalleſt volume it is capable of occupying.

In theſe combinations, the caloric exerts a conſtant action upon the oxygen, to bring it back to the ſtate of gas; hence the oxygen adheres but very ſlightly, and the ſmalleſt additional force is capable of ſetting it free; and, when ſuch force is applied, it often recovers the ſtate of gas inſtantaneouſly. This rapid paſſage from the ſolid to the aëriform ſtate is called detonation, or fulmination, becauſe it is uſually accompanied with noiſe and exploſion. Deflagrations are commonly produced by means of combinations of charcoal, either with nitre or

 with

with oxygenated muriat of potaſh; ſometimes, to aſſiſt the inflammation, ſulphur is added; and, upon the juſt proportion of theſe ingredients, and the proper manipulation of the mixture, the art of making gun-powder depends.

As oxygen is changed by deflagration with charcoal, into carbonic acid, inſtead of oxygen gas, carbonic acid gas is diſengaged, at leaſt when the mixture has been made in juſt proportions. In deflagration with nitre, azotic gas is likewiſe diſengaged, becauſe azot is one of the conſtituent elements of nitric acid.

The ſudden and inſtantaneous diſengagement and expanſion of theſe gaſes is not, however, ſufficient for explaining all the phenomena of deflagration; becauſe, if this were the ſole operating powder, gun-powder would always be ſo much the ſtronger in proportion as the quantity of gas diſengaged in a given time was the more conſiderable, which does not always accord with experiment. I have tried ſome kinds which produced almoſt double the effect of ordinary gun-powder, although they gave out a ſixth part leſs of gas during deflagration. It would appear that the quantity of caloric diſengaged at the moment of detonation contributes conſiderably to the expanſive effects produced; for, although caloric penetrates freely through the pores of every body in nature, it can only do ſo progreſſively, and in a given time: hence, when the

quantity difengaged at once is too large to get through the pores of the furrounding bodies, it muft neceffarily act in the fame way with ordinary elaftic fluids, and muft overturn every thing that oppofes its paffage. This muft, at leaft in part, take place when gun-powder is fet on fire in a cannon; as, although the metal is permeable to caloric, the quantity difengaged at once is too large to find its way through the pores of the metal; it muft therefore make an effort to efcape on every fide; and, as the refiftance all around, excepting towards the muzzle, is too great to be overcome, this effort is neceffarily employed for expelling the bullet.

The caloric produces a fecond effect, by means of the repulfive force exerted between its particles; it caufes the gafes, difengaged at the moment of deflagration, to expand with a degree of force proportioned to the temperature produced.

It is very probable, that water is decompofed during the deflagration of gun-powder, and that part of the oxygen furnifhed to the nafcent carbonic acid gas is produced from it. If fo, a confiderable quantity of hydrogen gas muft be difengaged in the inftant of deflagration, which expands, and contributes to the force of the explofion. It may readily be conceived how greatly this circumftance muft increafe the effect of powder, if we confider that a pint of hydrogen

gas weighs only one grain and two-thirds; hence a very ſmall quantity in weight muſt occupy a very large ſpace, and it muſt exert a prodigious expanſive force in paſſing from the liquid to the aëriform ſtate of exiſtence.

In the laſt place, as a portion of undecompoſed water is reduced to vapour during the deflagration of gun-powder, and as water, in the ſtate of gas, occupies ſeventeen or eighteen hundred times more ſpace than in its liquid ſtate, this circumſtance muſt likewiſe contribute largely to the exploſive force of the powder.

I have already made a conſiderable ſeries of experiments upon the nature of the elaſtic fluids diſengaged during the deflagration of nitre with charcoal and ſulphur, and have made ſome, likewiſe, with the oxygenated muriat of potaſh. This method of inveſtigation leads to tolerably accurate concluſions with reſpect to the conſtituent elements of theſe ſalts. Some of the principal reſults of theſe experiments, and of the conſequences drawn from them reſpecting the analyſis of nitric acid, are reported in the collection of Memoirs preſented to the Academy by foreign philoſophers, vol. xi. p. 625. Since then I have procured more convenient inſtruments, and I intend to repeat theſe experiments upon a larger ſcale, by which I ſhall procure more accurate preciſion in their reſults; the following, however, is the proceſs I have hitherto

employed.

employed. I would very earneſtly adviſe ſuch as intend to repeat ſome of theſe experiments, to be very much upon their guard in operating upon any mixture which contains nitre, charcoal and ſulphur, and more eſpecially with thoſe in which oxygenated muriat of potaſh is mixed with theſe two materials.

I make uſe of piſtol-barrels, about ſix inches long, and of five or ſix lines diameter, having the touch-hole ſpiked up with an iron-nail ſtrongly driven in, and broken in the hole, and a little tin-ſmith's ſolder run in to prevent any poſſible iſſue for the air. Theſe are charged with a mixture of known quantities of nitre and charcoal, or any other mixture capable of deflagration, reduced to an impalpable powder, and formed into a paſte with a moderate quantity of water. Every portion of the materials introduced muſt be rammed down with a rammer nearly of the ſame caliber with the barrel, four or five lines at the muzzle muſt be left empty, and about two inches of quick match are added at the end of the charge. The only difficulty in this experiment, eſpecially when ſulphur is contained in the mixture, is to diſcover the proper degree of moiſtening; for, if the paſte be too much wetted, it will not take fire, and if too dry, the deflagration is apt to become too rapid, and even dangerous.

When the experiment is not intended to be rigorously exact, we set fire to the match, and, when it is just about to communicate with the charge, we plunge the pistol below a large bell-glass full of water, in the pneumato-chemical apparatus. The deflagration begins, and continues in the water, and gas is disengaged with less or more rapidity, in proportion as the mixture is more or less dry. So long as the deflagration continues, the muzzle of the pistol must be kept somewhat inclined downwards, to prevent the water from getting into its barrel. In this manner I have sometimes collected the gas produced from the deflagration of an ounce and half, or two ounces, of nitre.

In this manner of operating, it is impossible to determine the quantity of carbonic acid gas disengaged, because a part of it is absorbed by the water while passing through it; but, when the carbonic acid is absorbed, the azotic gas remains; and, if it be agitated for a few minutes in caustic alkaline solution, we obtain it pure, and can easily determine its volume and weight. We may even, in this way, acquire a tolerably exact knowledge of the quantity of carbonic acid by repeating the experiment a great many times, and varying the proportions of charcoal, till we find the exact quantity requisite to deflagrate the whole nitre employed. Hence, by means of the weight of charcoal employed, we determine

determine the weight of oxygen neceſſary for ſaturation, and deduce the quantity of oxygen contained in a given weight of nitre.

I have uſed another proceſs, by which the reſults of this experiment are conſiderably more accurate, which conſiſts in receiving the diſengaged gaſes in bell-glaſſes filled with mercury. The mercurial apparatus I employ is large enough to contain jars of from twelve to fifteen pints in capacity, which are not very readily managed when full of mercury, and even require to be filled by a particular method. When the jar is placed in the ciſtern of mercury, a glaſs-ſyphon is introduced, connected with a ſmall air-pump, by means of which the air is exhauſted, and the mercury riſes ſo as to fill the jar. After this, the gas of the deflagration is made to paſs into the jar in the ſame manner as directed when water is employed.

I muſt again repeat, that this ſpecies of experiment requires to be performed with the greateſt poſſible precautions. I have ſometimes ſeen, when the diſengagement of gas proceeded with too great rapidity, jars filled with more than an hundred and fifty pounds of mercury driven off by the force of the exploſion, and broken to pieces, while the mercury was ſcattered about in great quantities.

When the experiment has ſucceeded, and the gas is collected under the jar, its quantity in

general, and the nature and quantities of the ſeveral ſpecies of gaſes of which the mixture is compoſed, are accurately aſcertained by the methods already pointed out in the ſecond chapter of this part of my work. I have been prevented from putting the laſt hand to the experiments I had begun upon deflagration, from their connection with the objects I am at preſent engaged in; and I am in hopes they will throw conſiderable light upon the operations belonging to the manufacture of gun-powder.

CHAP.

CHAP. X.

Of the Inſtruments neceſſary for Operating upon Bodies in very high Temperatures.

SECT. I.

Of Fuſion.

WE have already ſeen, that by aqueous ſolution, in which the particles of bodies are ſeparated from each other, neither the ſolvent nor the body held in ſolution are at all decompoſed; ſo that, whenever the cauſe of ſeparation ceaſes, the particles reunite, and the ſaline ſubſtance recovers preciſely the ſame appearance and properties it poſſeſſed before ſolution. Real ſolutions are produced by fire, or by introducing and accumulating a great quantity of caloric between the particles of bodies; and this ſpecies of ſolution in caloric is uſually called *fuſion*.

This operation is commonly performed in veſſels called crucibles, which muſt neceſſarily be

be lefs fufible than the bodies they are intended to contain. Hence, in all ages, chemifts have been extremely folicitous to procure crucibles of very refractory materials, or fuch as are capable of refifting a very high degree of heat. The beft are made of very pure clay or of porcelain earth; whereas fuch as are made of clay mixed with calcareous or filiceous earth are very fufible. All the crucibles made in the neighbourhood of Paris are of this kind, and are confequently unfit for moft chemical experiments. The Heffian crucibles are tolerably good; but the beft are made of Limoges earth, which feems abfolutely infufible. We have, in France, a great many clays very fit for making crucibles; fuch, for inftance, is the kind ufed for making melting-pots at the glafs manufactory of St Gobin.

Crucibles are made of various forms, according to the operations they are intended to perform. Several of the moft common kinds are reprefented Pl. VII. Fig. 7, 8, 9, and 10.; the one reprefented at Fig. 9. is almoft fhut at its mouth.

Though fufion may often take place without changing the nature of the fufed body, this operation is frequently employed as a chemical means of decompofing and recompounding bodies. In this way all the metals are extracted from their ores; and, by this procefs, they are revived,

moulded,

moulded, and alloyed with each other. By this procefs fand and alkali are combined to form glafs, and by it likewife paftes, or coloured ftones, enamels, &c. are formed.

The action of violent fire was much more frequently employed by the ancient chemifts than it is in modern experiments. Since greater precifion has been employed in philofophical refearches, the *humid* has been preferred to the *dry* method of procefs, and fufion is feldom had recourfe to until all the other means of analyfis have failed.

SECT. II.

Of Furnaces.

Thefe are inftruments of moft univerfal ufe in chemiftry; and, as the fuccefs of a great number of experiments depends upon their being well or ill conftructed, it is of great importance that a laboratory be well provided in this refpect. A furnace is a kind of hollow cylindrical tower, fometimes, widened above, Pl. XIII. Fig. 1. ABCD, which muft have at leaft two lateral openings; one in its upper part F, which is the door of the fire-place, and one below, G, leading

leading to the aſh-hole. Between theſe the furnace is divided by a horizontal grate intended for ſupporting the fuel, the ſituation of which is marked in the figure by the line HI. Though this be the leaſt complicated of all the chemical furnaces, yet it is applicable to a great number of purpoſes. By it lead, tin, biſmuth, and, in general, every ſubſtance which does not require a very ſtrong fire, may be melted in crucibles; it will ſerve for metallic oxydations, for evaporatory veſſels, and for ſand-baths, as in Pl. III. Fig. 1. and 2. To render it proper for theſe purpoſes, ſeveral notches, *m m m m*, Pl. XIII. Fig 1. are made in its upper edge, as otherwiſe any pan which might be placed over the fire would ſtop the paſſage of the air, and prevent the fuel from burning. This furnace can only produce a moderate degree of heat, becauſe the quantity of charcoal it is capable of conſuming is limited by the quantity of air which is allowed to paſs through the opening G of the aſh-hole. Its power might be conſiderably augmented by enlarging this opening, but then the great ſteam of air which is convenient for ſome operations might be hurtful in others; wherefore we muſt have furnaces of different forms, conſtructed for different purpoſes, in our laboratories: There ought eſpecially to be ſeveral of the kind now deſcribed of different ſizes.

The

The reverberatory furnace, Pl. XIII. Fig. 2. is perhaps more neceſſary. This, like the common furnace, is compoſed of the aſh-hole HIKL, the fire-place, KLMN, the laboratory, MNOP, and the dome RRSS, with its funnel or chimney TTVV; and to this laſt ſeveral additional tubes may be adapted, according to the nature of the different experiments. The retort A is placed in the diviſion called the laboratory, and is ſupported by two bars of iron which run acroſs the furnace, and its beak comes out at a round hole in the ſide of the furnace, one-half of which is cut in the piece called the laboratory, and the other in the dome. In moſt of the ready made reverberatory furnaces which are ſold by the potters at Paris, the openings both above and below are too ſmall: Theſe do not allow a ſufficient volume of air to paſs through; hence, as the quantity of charcoal conſumed, or, what is much the ſame thing, the quantity of caloric diſengaged, is nearly in proportion to the quantity of air which paſſes through the furnace, theſe furnaces do not produce a ſufficient effect in a great number of experiments. To remedy this defect, there ought to be two openings GG to the aſh-hole; one of theſe is ſhut up when only a moderate fire is required; and both are kept open when the ſtrongeſt power of the furnace is to be exerted. The opening of the dome SS ought likewiſe

likewiſe to be conſiderably larger than it is uſually made.

It is of great importance not to employ retorts of too large ſize in proportion to the furnace, as a ſufficient ſpace ought always to be allowed for the paſſage of the air between the ſides of the furnace and the veſſel. The retort A in the figure is too ſmall for the ſize of the furnace, yet I find it more eaſy to point out the error than to correct it. The intention of the dome is to oblige the flame and heat to ſurround and ſtrike back or reverberate upon every part of the retort, whence the furnace gets the name of reverberatory. Without this circumſtance the retort would only be heated in its bottom, the vapours raiſed from the continued ſubſtance would condenſe in the upper part, and a continual cohobation would take place without any thing paſſing over into the receiver; but, by means of this dome, the retort is equally heated in every part, and the vapours being forced out, can only condenſe in the neck of the retort, or in the recipient.

To prevent the bottom of the retort from being either heated or cooled too ſuddenly, it is ſometimes placed in a ſmall ſand-bath of baked clay, ſtanding upon the croſs bars of the furnace. Likewiſe, in many operations the retorts are coated over with lutes, ſome of which are intended to preſerve them from the too ſudden influence

influence of heat or of cold, while others are for ſuſtaining the glaſs, or forming a kind of ſecond retort, which ſupports the glaſs one during operations wherein the ſtrength of the fire might ſoften it. The former is made of brick-clay with a little cows hair beat up along with it, into a paſte or mortar, and ſpread over the glaſs or ſtone retorts. The latter is made of pure clay and pounded ſtone-ware mixed together, and uſed in the ſame manner. This dries and hardens by the fire, ſo as to form a true ſupplementary retort capable of retaining the materials, if the glaſs-retort below ſhould crack or ſoften. But, in experiments which are intended for collecting gaſes, this lute, being porous, is of no manner of uſe.

In a great many experiments, wherein very violent fire is not required, the reverberatory furnace may be uſed as a melting one, by leaving out the piece called the laboratory, and placing the dome immediately upon the fire-place, as repreſented Pl. XIII. Fig. 3. The furnace repreſented in Fig. 4. is very convenient for fuſions; it is compoſed of the fire-place and aſh-hole ABD, without a door, and having a hole E, which receives the muzzle of a pair of bellows ſtrongly luted on, and the dome ABGH, which ought to be rather lower than is repreſented in the figure. This furnace is not capable of producing a very ſtrong heat, but is ſufficient

ſufficient for ordinary operations, and may be readily moved to any part of the laboratory where it is wanted. Though theſe particular furnaces are very convenient, every laboratory muſt be provided with a forge-furnace, having a good pair of bellows, or what is more neceſſary, a powerful melting furnace. I ſhall deſcribe the one I uſe, with the principles upon which it is conſtructed.

The air circulates in a furnace in conſequence of being heated in its paſſage through the burning coals; it dilates, and, becoming lighter than the ſurrounding air, is forced to riſe upwards by the preſſure of the lateral columns of air, and is replaced by freſh air from all ſides, eſpecially from below. This circulation of air even takes place when coals are burnt in a common chaſing-diſh; but we can readily conceive, that, in a furnace open on all ſides, the maſs of air which paſſes, all other circumſtances being equal, cannot be ſo great as when it is obliged to paſs through a furnace in the ſhape of a hollow tower, like moſt of the chemical furnaces, and conſequently that the combuſtion muſt be more rapid in a furnace of this latter conſtruction. Suppoſe, for inſtance, the furnace ABCDEF (Fig. 5.) open above, and filled with burning coals, the force with which the air paſſes through the coals will be in proportion to the difference between the ſpecific gravity of two columns equal

equal to AC, the one of cold air without, and the other of heated air within the furnace. There muſt be ſome heated air above the opening AB, and the ſuperior levity of this ought likewiſe to be taken into conſideration; but, as this portion is continually cooled and carried off by the external air, it cannot produce any great effect.

But, if we add to this furnace a large hollow tube GHAB of the ſame diameter, which preſerves the air which has been heated by the burning coals from being cooled and diſperſed by the ſurrounding air, the difference of ſpecific gravity which cauſes the circulation will then be between two columns equal to GC. Hence, if GC be three times the length of AC, the circulation will have treble force. This is upon the ſuppoſition that the air in GHCD is as much heated as what is contained in ABCD, which is not ſtrictly the caſe, becauſe the heat muſt decreaſe between AB and GH; but, as the air in GHAB is much warmer than the external air, it follows, that the addition of the tube muſt increaſe the rapidity of the ſtream of air, that a larger quantity muſt paſs through the coals, and conſequently that a greater degree of combuſtion muſt take place.

We muſt not, however, conclude from theſe principles, that the length of this tube ought to be indefinitely prolonged; for, ſince the heat of

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the air gradually diminiſhes in paſſing from AB to GH, even from the contact of the ſides of the tube, if the tube were prolonged to a certain degree, we would at laſt come to a point where the ſpecific gravity of the included air would be equal to the air without; and, in this caſe, as the cool air would no longer tend to riſe upwards, it would become a gravitating maſs, reſiſting the aſcenſion of the air below. Beſides, as this air, which has ſerved for combuſtion, is neceſſarily mixed with carbonic acid gas, which is conſiderably heavier than common air, if the tube were made long enough, the air might at laſt approach ſo near to the temperature of the external air, as even to gravitate downwards; hence we muſt conclude, that the length of the tube added to a furnace muſt have ſome limit, beyond which it weakens, inſtead of ſtrengthening, the force of the fire.

From theſe reflections it follows, that the firſt foot of tube added to a furnace produces more effect than the ſixth, and the ſixth more than the tenth; but we have no data to aſcertain at what height we ought to ſtop. This limit of uſeful addition is ſo much the farther in proportion as the materials of the tube are weaker conductors of heat, becauſe the air will thereby be ſo much leſs cooled; hence baked earth is much preferable to plate iron. It would be even of conſequence to make the tube double, and

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to fill the interval with rammed charcoal, which is one of the worſt known conductors of heat; by this the refrigeration of the air will be retarded, and the rapidity of the ſtream of air conſequently increaſed; and, by this means, the tube may be made ſo much the longer.

As the fire-place is the hotteſt part of a furnace, and the part where the air is moſt dilated in its paſſage, this part ought to be made with a conſiderable widening or belly. This is the more neceſſary, as it is intended to contain the charcoal and crucible, as well as for the paſſage of the air which ſupports, or rather produces the combuſtion; hence we only allow the interſtices between the coals for the paſſage of the air.

From theſe principles my melting furnace is conſtructed, which I believe is at leaſt equal in power to any hitherto made, though I by no means pretend that it poſſeſſes the greateſt poſſible intenſity that can be produced in chemical furnaces. The augmentation of the volume of air produced during its paſſage through a melting furnace not being hitherto aſcertained from experiment, we are ſtill unacquainted with the proportions which ſhould exiſt between the inferior and ſuperior apertures, and the abſolute ſize of which theſe openings ſhould be made is ſtill leſs underſtood; hence data are wanting by which to proceed upon principle, and we

can only accomplish the end in view by repeated trials.

This furnace, which, according to the above-stated rules, is in form of an elliptical spheroid, is represented Pl. XIII. Fig. 6. ABCD; it is cut off at the two ends by two plains, which pass, perpendicular to the axis, through the foci of the ellipse. From this shape it is capable of containing a considerable quantity of charcoal, while it leaves sufficient space in the intervals for the passage of the air. That no obstacle may oppose the free access of external air, it is perfectly open below, after the model of Mr Macquer's melting furnace, and stands upon an iron tripod. The grate is made of flat bars set on edge, and with considerable interstices. To the upper part is added a chimney, or tube, of baked earth, ABFG, about eighteen feet long, and almost half the diameter of the furnace. Though this furnace produces a greater heat than any hitherto employed by chemists, it is still susceptible of being considerably increased in power by the means already mentioned, the principal of which is to render the tube as bad a conductor of heat as possible, by making it double, and filling the interval with rammed charcoal.

When it is required to know if lead contains any mixture of gold or silver, it is heated in a strong fire in capsules of calcined bones, which

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are called cuppels. The lead is oxydated, becomes vitrified, and ſinks into the ſubſtance of the cuppel, while the gold or ſilver, being incapable of oxydation, remain pure. As lead will not oxydate without free acceſs of air, this operation cannot be performed in a crucible placed in the middle of the burning coals of a furnace, becauſe the internal air, being moſtly already reduced by the combuſtion into azotic and carbonic acid gas, is no longer fit for the oxydation of metals. It was therefore neceſſary to contrive a particular apparatus, in which the metal ſhould be at the ſame time expoſed to the influence of violent heat, and defended from contact with air rendered incombuſtible by its paſſage through burning coals.

The furnace intended for anſwering this double purpoſe is called the cuppelling or eſſay furnace. It is uſually made of a ſquare form, as repreſented Pl. XIII. Fig. 8. and 10. having an aſh-hole AABB, a fire-place BBCC, a laboratory CCDD, and a dome DDEE. The muffle or ſmall oven of baked earth GH, Fig. 9. being placed in the laboratory of the furnace upon croſs bars of iron, is adjuſted to the opening GG, and luted with clay ſoftened in water. The cuppels are placed in this oven or muffle, and charcoal is conveyed into the furnace through the openings of the dome and fire-place. The external air enters through the openings of the aſh-

 hole

hole for ſupporting the combuſtion, and eſcapes by the ſuperior opening or chimney at EE; and air is admitted through the door of the muffle GG for oxydating the contained metal.

Very little reflection is ſufficient to diſcover the erroneous principles upon which this furnace is conſtructed. When the opening GG is ſhut, the oxydation is produced ſlowly, and with difficulty, for want of air to carry it on; and, when this hole is open, the ſtream of cold air which is then admitted fixes the metal, and obſtructs the proceſs. Theſe inconveniences may be eaſily remedied, by conſtructing the muffle and furnace in ſuch a manner that a ſtream of freſh external air ſhould always play upon the ſurface of the metal, and this air ſhould be made to paſs through a pipe of clay kept continually red hot by the fire of the furnace. By this means the inſide of the muffle will never be cooled, and proceſſes will be finiſhed in a few minutes, which at preſent require a conſiderable ſpace of time.

Mr Sage remedies theſe inconveniences in a different manner; he places the cuppel containing lead, alloyed with gold or ſilver, amongſt the charcoal of an ordinary furnace, and covered by a ſmall porcelain muffle; when the whole is ſufficiently heated, he directs the blaſt of a common pair of hand-bellows upon the ſurface of

of the metal, and completes the cuppellation in this way with great eafe and exactnefs.

SECT. III.

Of increafing the Action of Fire, by ufing Oxygen Gas inftead of Atmofpheric Air.

By means of large burning-glaffes, fuch as thofe of Tchirnhaufen and of Mr de Trudaine, a degree of heat is obtained fomewhat greater than has hitherto been produced in chemical furnaces, or even in the ovens of furnaces ufed for baking hard porcelain. But thefe inftruments are extremely expenfive, and do not even produce heat fufficient to melt crude platina; fo that their advantages are by no means fufficient to compenfate for the difficulty of procuring, and even of ufing them. Concave mirrors produce fomewhat more effect than burning-glaffes of the fame diameter, as is proved by the experiments of Meffrs Macquer and Beaumé with the fpeculum of the Abbé Bouroit; but, as the direction of the reflected rays is neceffarily from below upwards, the fubftance to be operated upon muft be placed in the air without any fupport, which renders moft chemical experiments impoffible to be performed with this inftrument.

For theſe reaſons, I firſt endeavoured to employ oxygen gas in combuſtion, by filling large bladders with it, and making it paſs through a tube capable of being ſhut by a ſtop-cock; and in this way I ſucceeded in cauſing it to ſupport the combuſtion of lighted charcoal, The intenſity of the heat produced, even in my firſt attempt, was ſo great as readily to melt a ſmall quantity of crude platina. To the ſucceſs of this attempt is owing the idea of the gazometer, deſcribed p. 18. *et ſeq.* which I ſubſtituted inſtead of the bladders; and, as we can give the oxygen gas any neceſſary degree of preſſure, we can with this inſtrument keep up a continued ſtream, and give it even a very conſiderable force.

The only apparatus neceſſary for experiments of this kind conſiſts of a ſmall table, ABCD, Pl. XII. Fig. 15. with a hole F, through which paſſes a tube of copper or ſilver, ending in a very ſmall opening at G, and capable of being opened or ſhut by the ſtop-cock H. This tube is continued below the table at *l m n o*, and is connected with the interior cavity of the gazometer. When we mean to operate, a hole of a few lines deep muſt be made with a chiſel in a piece of charcoal, into which the ſubſtance to be treated is laid; the charcoal is ſet on fire by means of a candle and blow-pipe, after which it is expoſed

posed to a rapid stream of oxygen gas from the extremity G of the tube FG.

This manner of operating can only be used with such bodies as may be placed, without inconvenience, in contact with charcoal, such as metals, simple earths, &c. But for bodies whose elements have affinity to charcoal, and which are consequently decomposed by that substance, such as sulphats, phosphats, and most of the neutral salts, metallic glasses, enamels, &c. we must use a lamp, and make the stream of oxygen gas pass through its flame. For this purpose, we use the elbowed blow-pipe ST, instead of the bent one FG, employed with charcoal. The heat produced in this second manner is by no means so intense as in the former way, and is very difficultly made to melt platina. In this manner of operating with the lamp, the substances are placed in cuppels of calcined bones, or little cups of porcelain, or even in metallic dishes. If these last are sufficiently large, they do not melt, because metals being good conductors of heat, the caloric spreads rapidly through the whole mass, so that none of its parts are very much heated.

In the Memoirs of the Academy for 1782, p. 476. and for 1783, p. 573, the series of experiments I have made with this apparatus may be seen at large. The following are some of the principal results.

1. Rock cryſtal, or pure ſiliceous earth, is infuſible, but becomes capable of being ſoftened or fuſed when mixed with other ſubſtances.

2. Lime, magneſia, and barytes, are infuſible, either when alone, or when combined together, but eſpecially lime; they aſſiſt the fuſion of every other body.

3. Argil, or pure baſe of alum, is completely fuſible *per ſe* into a very hard opake vitreous ſubſtance, which ſcratches glaſs like the precious ſtones.

4. All the compound earths and ſtones are readily fuſed into a browniſh glaſs.

5. All the ſaline ſubſtances, even fixed alkali, are volatilized in a few ſeconds.

6. Gold, ſilver, and probably platina, are ſlowly volatilized without any particular phenomenon.

7. All other metallic ſubſtances, except mercury, become oxydated, though placed upon charcoal, and burn with different coloured flames, and at laſt diſſipate altogether.

8. The metallic oxyds likewiſe all burn with flames. This ſeems to form a diſtinctive character for theſe ſubſtances, and even leads me to believe, as was ſuſpected by Bergman, that barytes is a metallic oxyd, though we have not hitherto been able to obtain the metal in its pure or reguline ſtate.

9. Some

9. Some of the precious ſtones, as rubies, are capable of being ſoftened and ſoldered together, without injuring their colour, or even diminiſhing their weights. The hyacinth, though almoſt equally fixed with the ruby, loſes it colour very readily. The Saxon and Braſilian topaz, and the Braſilian ruby, loſe their colour very quickly, and loſe about a fifth of their weight, leaving a white earth, reſembling white quartz, or unglazed china. The emerald, chryſolite, and garnet, are almoſt inſtantly melted into an opake and coloured glaſs.

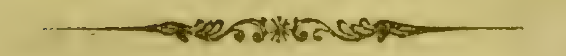
10. The diamond preſents a property peculiar to itſelf; it burns in the ſame manner with combuſtible bodies, and is entirely diſſipated.

There is yet another manner of employing oxygen gas for conſiderably increaſing the force of fire, by uſing it to blow a furnace. Mr Achard firſt conceived this idea; but the proceſs he employed, by which he thought to dephlogiſticate, as it is called, atmoſpheric air, or to deprive it of azotic gas, is abſolutely unſatisfactory. I propoſe to conſtruct a very ſimple furnace, for this purpoſe, of very refractory earth, ſimilar to the one repreſented Pl. XIII. Fig. 4. but ſmaller in all its dimenſions. It is to have two openings, as at E, through one of which the nozzle of a pair of bellows is to paſs, by which the heat is to be raiſed as high as poſſible with common air; after which, the ſtream

ſtream of common air from the bellows being ſuddenly ſtopt, oxygen gas is to be admitted through a tube, at the other opening, communicating with a gazometer having the preſſure of four or five inches of water. I can in this manner unite the oxygen gas from ſeveral gazometers, ſo as to make eight or nine cubical feet of gas paſs through the furnace; and in this way I expect to produce a heat greatly more intenſe than any hitherto known. The upper orifice of the furnace muſt be carefully made of conſiderable dimenſions, that the caloric produced may have free iſſue, leſt the too ſudden expanſion of that highly elaſtic fluid ſhould produce a dangerous exploſion.

APPEN-

APPENDIX.



No. I.

TABLE *for Converting Lines, or Twelfth Parts of an Inch, and Fractions of Lines, into Decimal Fractions of the Inch.*

Twelfth Parts of a line.	Decimal Fractions.	Lines.	Decimal Fractions.
1	0.00694	1	0.08333
2	0.01389	2	0.16667
3	0.02083	3	0.25000
4	0.02778	4	0.33333
5	0.03472	5	0.41667
6	0.04167	6	0.50000
7	0.04861	7	0.58333
8	0.05556	8	0.66667
9	0.06250	9	0.75000
10	0.06944	10	0.83333
11	0.07639	11	0.91667
12	0.08333	12	1.00000

No.

No. II.

TABLE *for Converting the observed Heights of Water in the Jars of the Pneumato-Chemical Apparatus, expressed in Inches and Decimals, to Corresponding Heights of Mercury.*

Water.	Mercury.	Water.	Mercury.
.1	.00737	4.	.29480
.2	.01474	5.	.36851
.3	.02201	6.	.44221
.4	.02948	7.	.51591
.5	.03685	8.	.58961
.6	.04422	9.	.66332
.7	.05159	10.	.73702
.8	.05896	11.	.81072
.9	.06633	12.	.88442
1.	.07370	13.	.96812
2.	.14740	14.	1.04182
3.	.22010	15.	1.11525

No.

No. III.

TABLE *for converting the Ounce Measures used by Dr Priestley into French and English Cubical Inches* *.

Ounce Measures.	French cubical Inches.	English cubical inches.
1	1.567	1.898
2	3.134	3.796
3	4.701	5.694
4	6.268	7.592
5	7.835	9.490
6	9.402	11.388
7	10.969	13.286
8	12.536	15.184
9	14.103	17.082
10	15.670	18.980
20	31.340	37.960
30	47.010	56.940
40	62.680	75.920
50	78.350	94.900
60	94.020	113.880
70	109.690	132.860
80	125.360	151.840
90	141.030	170.820
100	156.700	189.800
1000	1567.000	1898.000

No.

* The ounce measure of Dr Priestley contains an ounce troy, or 480 grains, of pure water. The cubical contents, as given in the above table, are retained from the French of

No. IV. Additional.

Rules *for Reducing the Degrees of Reaumeurs and of the Swediſh Thermometer, to the Correſponding degrees on Fahrenheits Scale* *.

The ſcale of Fahrenheits thermometer is divided into 212 degrees from Zero, the cold produced by a freezing mixture of ſalt and ſnow, to the temperature of boiling water: Reaumeurs ſcale has the Zero placed at the temperature of freezing water or melting ice, and the interval between that and the temperature of boiling water is divided into 80 degrees: The Swediſh thermometer has its Zero in the ſame place with that of Reaumeur, and the interval to the point of boiling water is divided into 100 degrees. Theſe are the principal thermometers now uſed in Europe, and the temperature indicated by any

of Mr Lavoiſier, reducing the French meaſure to Engliſh according to the beſt and moſt generally received compariſon of the ratio, as given more at large in No. V. of this appendix. If, however, the experiments of Mr Everard be followed, as noticed in No. IX. of the appendix, the Engliſh cubical meaſure of one ounce ought to have been 1.8959, inſtead of the above.—T.

* In a former edition of this tranſlation, a table was given of the degrees on Reaumeurs ſcale, with the correſponding degrees of Fahrenheit, from freezing to boiling water; but the formulæ in this article were thought more generally uſeful and more convenient.—T.

any of them may be reduced into the corre-ſponding degrees on any of the others by means of the following ſimple canons; in which R ſig-nifies the degrees on the ſcale of Reaumeur, F thoſe of Fahrenheit, and S thoſe of the Swediſh thermometer.

1. To convert the degrees of Reaumeur to thoſe of Fahrenheit; $\frac{R \times 9}{4} + 32 = F$.

2. To convert the degrees of Fahrenheit to thoſe of Reaumeur; $\frac{F - 32 \times 4}{9} = R$.

3. To convert the Swediſh degrees to thoſe of Fahrenheit; $\frac{S \times 9}{5} + 32 = F$.

4. To convert Fahrenheits to Swediſh; $\frac{F - 32 \times 5}{9} = S$.

5. To convert Swediſh degrees to thoſe of Reaumeur; $\frac{S \times 4}{5} = R$.

6. To convert Reaumeurs degrees to Swediſh; $\frac{R \times 5}{4} = S$.

To ſuch readers as are unacquainted with the algebraic expreſſion of arithmetical formulæ, it will be ſufficient to expreſs one or two of theſe in words to explain their uſe.—1. Multiply the degree of Reaumeur by 9, divide the product by 4, and to the quotient add 32, the ſum expreſſes the degree on the ſcale of Fahrenheit.—2. From the degree of Fahrenheit ſubtract 32, multiply

multiply the remainder by 4, and divide the product by 9, the quotient is the degree according to the ſcale of Reaumeur, &c.

No. V. Additional.

Rules *for Converting French Weights and Meaſures into correſpondent Engliſh Denominations**.

§ 1. *Weights.*

The Paris pound, poids de mark of Charlemagne, contains 9216 Paris grains; it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 Engliſh Troy grains.

The Engliſh Troy pound of 12 ounces contains 5760 Engliſh Troy grains, and is equal to 7021 Paris grains.

The Engliſh averdupois pound of 16 ounces contains 7000 Engliſh Troy grains, and is equal to 8538 Paris grains.

To reduce Paris *grs.* to Engliſh Troy *grs.* divide by - - -	1.2189
To reduce Engliſh Troy *grs.* to Paris *grs.* multiply by - - -	1.2189

To

* For the materials of this Article the Tranſlator is indebted to Profeſſor Robiſon.—T.

To reduce Paris ounces to English Troy, divide by - -	}	1.015734
To reduce English Troy ounces to Paris, multiply by - -	}	1.015734

Or the converſion may be made by means of the following Tables.

I. *To Reduce French to Engliſh Troy Weight.*

The Paris pound	=	7561	English Troy Grains.
The ounce	=	472.5625	
The gros	=	59.0703	
The grain	=	.8204	

II. *To Reduce Engliſh Troy to Paris Weight.*

The English Troy pound of 12 ounces,	=	7021.	Paris grains.
The Troy ounce,	=	585.0833	
The dram of 60 grs.	=	73.1354	
The penny-weight, or denier, of 24 grs.	=	29.2541	
The ſcruple, of 20 grs.	=	24.3784	
The grain,	=	1.2189	

III. *To Reduce Engliſh Averdupois to Paris Weight.*

The averdupois pound of 16 ounces, or 7000 Troy grains,	=	8538.	Paris grains.
The ounce, -	=	533.6250	

§ 2.

§ 2. *Long and Cubical Measures.*

To reduce Paris running feet or inches into English, multiply by English running feet or inches into Paris, divide by - -	1.065977
To reduce Paris cubic feet or inches to English, multiply by - English cubic feet or inches to Paris, divide by - -	1.211278

Or by means of the following tables:

IV. *To Reduce Paris Long Measure to English.*

The Paris royal foot of 12 inches, -	=	12.7977	English inches.
The inch, -	=	1.0659	
The line, or $\frac{1}{12}$ of an inch,	=	.0888	
The $\frac{1}{12}$ of a line, -	=	.0074	

V. *To Reduce English Long Measure to French.*

The English foot,	=	11.2596	Paris inches.
The inch, -	=	.9383	
The $\frac{1}{8}$ of an inch,	=	.1173	
The $\frac{1}{10}$, -	=	.0938	
The line, or $\frac{1}{12}$	=	.0782	

VI.

VI. *To Reduce French Cube Measure to English.*

The Paris cube foot = 1.211278	English cubical feet, or	2093.088384	inches.
The cubic inch = .000700		1.211278	

VII. *To Reduce English Cube Measure to French**.

The English cube foot, or 1728 cubical inches	=	1427.4864	Frnch cubical inches.
The cubical inch	=	.8260	
The cube tenth	=	.0008	

§ 3. *Measure of Capacity.*

The Paris pint contains 58.145 † English cubical inches, and the English wine pint contains

* To convert the weight of a French cubic foot of any particular substance given in French grains into the corresponding weight of an English cubic foot in English troy grains; multiply the French grains by 0.6773181, and the product is the number of English troy grains contained in an English cubic foot of the same substance.

† It is said by Belidor, *Archit. Hydrog.* to contain 31 *oz.* 54 *grs.* of water, which makes it 58.075 English inches; but, as there is considerable uncertainty in the determinations

28.875 * cubical inches; or, the Paris pint contains 2.0171082 English pints, and the English pint contains .49617 Paris pints; hence,

To reduce the Paris pint to the English, multiply by - -	2.0171082
To reduce the English pint to the Paris, divide by - -	

The Septier of Paris is 7736 French, or 9370.45 English, cubical inches; and the Muid is 92832 French, or 112445.4 English cubical inches.

No.

tions of the weight of the French cubical measure of water, owing to the uncertainty of the standards made use of, it is better to abide by Mr Everards measure, which was made by the Exchequer standards, and by the proportions of the English and French foot, as established by the French Academy and Royal Society.

* According to Beaumé, the Paris pint contains 32 French ounces of water, at the temperature of 54.5° of Fahrenheit; which would make it equal to 53.729 English cubical inches.

No. VI. Additional.

Rules *for Reducing the Swedish Weights and Measures, used by the Celebrated Bergman and Scheele, to English Denominations* *.

The Swedish pound, which is divided like the English Apothecary or Troy pound, weighs 6556 *grs.* troy.

The Kanne of pure water according to Bergman, weighs 42250 Swedish grains, and occupies 100 Swedish cubical inches. Hence the Kanne of pure water weighs 48088.719444 English troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inches.

From these data, the following rules are deduced.

1. To reduce Swedish longitudinal inches to English — Multiply by 1.2384, or divide by 0.80747.

2. To reduce Swedish to English cubical inches—Multiply by 1.9, or divide by 0.5265.

* For this article, which was added in the second edition, I am indebted to the friendly assistance of Dr Rotheram.—T.

3. To reduce the Swediſh pound, ounce, dram, ſcruple, or grain, to the correſponding Engliſh troy denomination, multiply by 1.1382, or divide by .8786.

4. To reduce the Swediſh Kannes to Engliſh wine pints, multiply by .1520207, or divide by 6.57804.

5. The Lod, a weight ſometimes uſed by Bergman, is the 32d part of the Swediſh pound; Therefore to reduce it to the Engliſh troy pound, multiply by .03557, or divide by 28.1156.

No. VII.

TABLE *of the Weights of the different Gases, at 28 French inches, or 29.85 English inches barometrical pressure, and at 54.5° of temperature, expressed in English measure and English Troy weight.*

Names of the Gases.	Specific gravity. water being 1000.	Weight of a cubical foot in grs.	Weight of a cubical inch in grs.
Atmospheric *	1.2308	538.45	.311023
Azotic	1.1890	520.17	.243154
Oxygen	1.3562	593.32	.343345
Hydrogen	0.094671	41.41	.023964
Carbonic acid	1.8454	807.34	.467326
* *			
Nitrous	1.4631	640.09	.370422
Ammoniacal	0.73539	321.72	.186180
Sulphurous acid	1.8856	824.98	.471631

No.

* These five were ascertained by Mr Lavoisier himself.—T.

** The last three are inserted by Mr Lavoisier upon the authority of Mr Kirwan.—T.

No. VIII.

Tables *of the Specific Gravities of different Bodies.*

§ 1. *Metallic Substances.*

GOLD.

Pure gold of 24 carats melted, but not hammered, - -	19.2581
The same hammered, -	19.3617
Gold of the Parisian standard, 22 carats fine, not hammered *, -	17.4863
The same hammered, -	17.5894
Gold of the standard of French coin, $21\frac{22}{32}$ carats fine, not hammered,	17.4022
The same coined, - -	17.6474
Gold of the French trinket standard, 20 carrats fine, not hammered,	15.7090
The same hammered, - -	15.7746

SILVER.

Pure or virgin silver, 12 deniers, not hammered, - -	10.4743
The same hammered, -	10.5107
Silver of the Paris standard, 11 deniers 10 grains fine, not hammered †,	10.1572
The same hammered, -	10.3765

Silver,

* The same with Sterling.

† This is 10 *grs.* finer than Sterling.

Silver, ſtandard of French coin, 10 deniers 21 grains fine, not hammered,	10.0476
The ſame coined, - -	10.4077

PLATINA.

Crude platina in grains, -	15.6017
The ſame, after being treated with muriatic acid, - -	16.7521
Purified platina, not hammered,	19.5000
The ſame hammered, -	20.3366
The ſame drawn into wire, -	21.0417
The ſame paſſed through rollers,	22.0690

COPPER AND BRASS.

Copper not hammered, -	7.7880
The ſame wire drawn, - -	8.8785
Braſs not hammered, -	8.3958
The ſame wire drawn, -	8.5441
Common caſt braſs, - -	7.8240

IRON AND STEEL.

Caſt iron, - - -	7.2070
Bar iron, either hardened or not,	7.7880
Steel, neither tempered nor hardened,	7.8331
Steel, hardened under the hammer, but not tempered, - -	7.8404
Steel, tempered and hardened,	7.8180
Steel, tempered and not hardened,	7.8163

OTHER

OTHER METALS.

Pure tin from Cornwall melted and not hardened, - -	7.2914
The ſame hardened, - -	7.2994
Malacca tin, not hardened, -	7.2963
The ſame hardened, - -	7.3065
Molten lead, - -	11.3523
Molten zinc, - -	7.1908
Molten biſmuth, - -	9.8227
Molten cobalt, - -	7.8119
Molten arſenic, - -	5.7633
Molten nickel, - -	7.8070
Molten antimony, - -	6.7021
Crude antimony, - -	4.0643
Glaſs of antimony, - -	4.9464
Molybdena, - -	4.7385
Tungſtein, - -	6.0665
Mercury, - -	13.5681
Uranium, - -	6.4400

§ 2. *Precious Stones.*

White Oriental diamond, -	3.5212
Roſe-coloured Oriental ditto, -	3.5310
Oriental ruby, - -	4.2833
Spinell ditto, - -	3.7600
Ballas ditto, - -	3.6458
Braſilian ditto, - -	3.5311
Oriental topas, - -	4.0106

Oriental

Oriental Piſtachio topas - -	4.0615
Braſilian ditto - -	3.5365
Saxon ditto - -	3.5640
Ditto white ditto - -	3.5535
Oriental Saphir - -	3.9941
Ditte white ditto - -	3.9911
Saphire of Puy - -	4.0769
Ditto of Braſil - -	3.1307
Giraſol - -	4.0000
Ceylon jargon - -	4.4161
Hyacinth - -	3.6873
Vermilion - -	4.2299
Bohemian garnet - -	4.1888
Dodecahedral ditto -	4.0627
Syrian ditto - -	4.0000
Volcanic ditto with 24 ſides -	2.4684
Peruvian emerald - -	2.7755
Cryſolite of the jewellers -	2.7821
Ditto of Braſil - -	2.6923
Beryl or Oriental aqua marine -	3.5489
Occidental aqua marine -	2.7227

§ 3. *Siliceous Stones.*

Pure rock cryſtal of Madagaſcar -	2.6530
Ditto of Braſil - -	2.6526
Ditto of Europe, or gelatinous -	2.6548
Cryſtallized quarts - -	2.6546
Amorphous ditto - -	2.6471
Oriental agate - -	2.5901

Agate

Agate onyx - -	2.6375
Tranſparent calcedony -	2.6640
Carnelian - -	2.6137
Sardonyx - -	2.6025
Praſe - -	2.5805
Onyx pebble - -	2.6644
Pebble of Rennes - -	2.6538
White jade - -	2.9502
Green jade - -	2.9660
Red jaſper - -	2.6612
Brown ditto - -	2.6911
Yellow ditto - -	2.7101
Violet ditto - -	2.7111
Grey ditto - -	2.7640
Jaſponyx, - -	2.8160
Black priſmatic hexahedral ſchorl	3.3852
Black ſpary ditto - -	3.3852
Black amorphous ſchorl, called antique baſaltes - -	2.9225
Paving ſtone - -	2.4158
Grind ſtone - -	2.1429
Cutler's ſtone - -	2.1113
Fountainbleau ſtone - -	2.5616
Scythe ſtone of Auvergne -	2.5638
Ditto of Lorrain - -	2.5298
Mill ſtone - -	2.4835
White flint - -	2.5941
Blackiſh ditto - -	2.5817

§ 4.

§ 4. *Various Stones, &c.*

Opake green Italian ſerpentine, or gabro of the Florentines - -	2.4295
Coarſe Briançon chalk -	2.7274
Spaniſh chalk - -	2.7902
Foliated lapis ollaris of Dauphiny	2.7687
Ditto ditto from Sweden -	2.8531
Muſcovy talc - -	2.7917
Black mica - -	2.9004
Common ſchiſtus or ſlate -	2.6718
New ſlate - -	2.8535
White razor hone -	2.8763
Black and white hone -	3.1311
Rhombic or Iceland cryſtal -	2.7151
Pyramidal calcareous ſpar -	2.7302
Oriental or white antique alabaſter	2.7141
Green Campan marble -	2.7417
Red Campan marble -	2.7242
White Carara marble -	2.7168
White Parian marble -	2.8376
Various kinds of Calcareous ſtones used in France for building	from 1.3864 to 2.3902
Ore of Uranium - -	7.5000
Heavy ſpar - -	4.4300
Strontitic ſpar - -	3.7260 / 3.6500
White fluor - -	3.1555
Red ditto - -	3.1911
Green ditto - -	3.1817
Blue ditto - -	3.1688

Violet

Violet fluor - -	3.1757
Red ſcintilant zeolite from Edelfors	2.4868
White ſcintilant zeolite -	2.0739
Cryſtallized zeolite - -	2.0833
Black pitch ſtone - -	2.0499
Yellow pitch ſtone - -	1.0860
Red ditto - -	2.6695
Blackiſh ditto - -	2.3191
Red porphyry - -	2.7651
Ditto of Dauphiny - -	2.7033
Green ſerpentine - -	2.8960
Black ditto of Dauphiny, called variolite	2.9339
Green ditto from Dauphiny -	2.9883
Ophites - -	2.9722
Granitello - -	3.0626
Red Egyptian granite -	2.6541
Beautiful red granite -	2.7609
Granite of Girardmas -	2.7163
Pumice ſtone - -	.9145
Lapis obſidianus - -	2.3480
Pierre de Volvic - -	2.3205
Touch ſtone - -	2.4153
Baſaltes from Giants Cauſeway	2.8642
Ditto priſmatic from Auvergne -	2.4153
Glaſs gall - -	2.8548
Bottle glaſs - -	2.7325
Green glaſs - -	2.6423
White glaſs - -	2.8922
St Gobin cryſtal - -	2.4882
Leith cryſtal - -	3.1890

Flint

Flint glaſs	3.3293
Borax glaſs	2.6070
Seves porcelain	2.1457
Limoges ditto	2.3410
China ditto	2.3847
Native ſulphur	2.0332
Melted ſulphur	1.9907
Phoſphorus	1.7140
Hard peat	1.3290
Ambergreaſe	.9263
Yellow tranſparent amber	1.0780

§ 5. *Liquids.*

Diſtilled water	1.0000
Rain water	1.0000
Filtered water of the Seine	1.00015
Arcueil water	1.00046
Avray water	1.00043
Sea water	1.0263
Water of the Dead Sea	1.2403
Burgundy wine	.9915
Bourdeaux ditto	.9939
Malmſey Madeira	1.0382
Red beer	1.0338
White ditto	1.0231
Cyder	1.0181
Highly rectified alcohol	.8293
Common ſpirits of wine	.8371

Alcohol, 15 pts.;	water, 1 part.	.8527
14	2	.8674
13	3	.8815
12	4	.8947
11	5	.9075
10	6	.9199
9	7	.9317
8	8	.9427
7	9	.9519
6	10	.9594
5	11	.9674
4	12	.9733
3	13	.9791
2	14	.9852
1	15	.9919

Sulphuric ether, -	.7394
Nitric ether, - -	.9088
Muriatic ether, - -	.7298
Acetic ether, - -	.8664
Highly concentrated Sulphuric acid,	2.1250
Common Sulphuric acid, -	1.8409
Highly concentrated Nitric acid,	1.5800
Common Nitric ditto, -	1.2715
Muriatic ditto, - -	1.1940
Fluoric acid, - -	1.5000
Red acetous ditto, - -	1.0251
White acetous ditto, -	1.0135
Diftilled ditto, ditto, -	1.0095

Acetic

Acetic ditto - -	1.0626
Formic ditto - -	.9942
Solution of cauftic ammoniac, or volatile alkali fluor - -	.8970
Effential or volatile oil of turpentine	.8697
Liquid turpentine - -	.9910
Volatile oil of lavender -	.8938
Volatile oil of cloves -	1.0363
Volatile oil of cinnamon -	1.0439
Oil of olives - -	.9153
Oil of fweet almonds - -	.9170
Lintfeed oil - -	.9403
Oil of poppy feed -	.9288
Oil of beech maft -	.9176
Whale oil - -	.9233
Womans milk - -	1.0203
Mares milk - -	1.0346
Afs milk - -	1.0355
Goats milk - -	1.0341
Ewe milk - -	1.0409
Cows milk - -	1.0324
Cow whey - -	1.0193
Human urine - -	1.0106

§ 6. *Refins and Gums.*

Common yellow or white rofin	1.0727
Arcanfon - -	1.0857

 Galipot

Galipot *	-	-	1.0819
Baras *	-	-	1.0441
Sandarac	-	-	1.0920
Maſtic	-	-	1.0742
Storax	-	-	1.1098
Opake copal	-	-	1.1398
Tranſparent ditto	-	-	1.0452
Madagaſcar ditto	-	-	1.0600
Chineſe ditto	-	-	1.0628
Elemi	-	-	1.0182
Oriental anime	-	-	1.0284
Occidental ditto	-	-	1.0426
Labdanum	-	-	1.1862
Ditto *in tortis*	-	-	2.4933
Reſin of guaiac	-	-	1.2289
Ditto of jallap	-	-	1.2185
Dragons blood	-	-	1.2045
Gum lac	-	-	1.1390
Tacamahaca	-	-	1.0463
Benzoin	-	-	1.0924
Alouchi †	-	-	1.0604
Caragna ‡	-	-	1.1244
Elaſtic gum	-	-	.9335
Camphor	-	-	.9887
Gum ammoniac	-	-	1.2071
Sagapenum	-	-	1.2008

Ivy

* Reſinous juices extracted in France from the Pine. Vide *Bomares Dict.*

† Odoriferous gum from the tree which produces the Cortex Winteranus. *Ibid.*

‡ Reſin of the tree called in Mexico, Caragna, or Tree of Madneſs. *Ibid.*

Ivy gum * - -	1.2948
Gamboge - -	1.2216
Euphorbium - -	1.1244
Olibanum - -	1.1732
Myrrh - -	1.3600
Bdellium - -	1.3717
Aleppo Scamony - -	1.2354
Smyrna ditto - -	1.2743
Galbanum - -	1.2120
Assafœtida - -	1.3275
Sarcocolla - -	1.2684
Opoponax - -	1.6226
Cherry-tree gum - -	1.4817
Gum Arabic - -	1.4523
Tragacanth - -	1.3161
Basora gum - -	1.4346
Acajou gum † - -	1.4456
Monbain gum ‡ - -	1.4206
Inspissated juice of liquorice -	1.7228
———————— Acacia -	1.5153
———————— Areca -	1.4573
Terra Japonica - -	1.3980
Hepatic aloes - -	1.3586
Socotrine aloes - -	1.3795
Inspissated juice of St Johns wort -	1.5263

* Extracted in Persia and the warm countries from Hedera terrestris.—*Bomare.*

† From a Brasilian tree of this name.—*Ibid.*

‡ From a tree of this name.—*Ibid.*

Opium - - -	1.3366
Indigo - - -	.7690
Arnotto - - -	.5956
Yellow wax - - -	.9648
White ditto - -	.9686
Ouarouchi ditto * - - -	.8970
Cacao butter, - - -	.8916
Spermaceti - -	.9433
Beef fat - - -	.9232
Veal fat - -	.9342
Mutton fat - - -	.9235
Tallow - - -	.9419
Hogs fat - - -	.9368
Lard - -	.9478
Butter - - -	.9423

§ 7. *Woods.*

Heart of oak 60 years old -	1.1700
Cork - - -	.2400
Elm trunk - -	.6710
Ash ditto - -	.8450
Beech - - -	.8520
Alder - -	.8000
Maple - -	.7550
Walnut - -	.6710
Willow - -	.5850
Linden - -	.6040

Male

* The produce of the Tallow Tree of Guiana. Vide *Bomares Dict.*

Male fir	-	-	.5500
Female ditto	-	-	.4980
Poplar	-	-	.3830
White Spaniſh ditto	-	-	.5294
Apple tree	-	-	.7930
Pear tree	-	-	.6610
Quince tree	-	-	.7050
Medlar	-	-	.9440
Plumb tree	-	-	.7850
Olive wood	-	-	.9270
Cherry tree	-	-	.7150
Filbert tree	-	-	.6000
French box	-	-	.9120
Dutch ditto	-	-	1.3280
Dutch yew	-	-	.7880
Spaniſh ditto	-	-	.8070
Spaniſh cypreſs	-	-	.6440
American cedar	-	-	.5608
Pomegranate tree	-	-	1.3540
Spaniſh mulberry tree		-	.8970
Lignum vitæ	-	-	1.3330
Orange tree	-	-	.7050

Note.—The numbers in the above Table, if the Decimal point be carried three figures farther to the right hand, nearly expreſs the abſolute weight of an Engliſh cube foot of each ſubſtance in averdupois ounces. See No. IX. of the Appendix.—T.

No. IX. Additional.

Rules *for Calculating the Absolute Gravity in English Troy Weight of a Cubic Foot and Inch, English Measure, of any Substance whose Specific Gravity is known* *.

In 1696, Mr Everard, balance-maker to the Exchequer, weighed before the Commissioners of the House of Commons 2145.6 cubical inches, by the Exchequer standard foot, of distilled water, at the temperature of 55° of Fahrenheit, and found it to weigh 1131 oz. 14 drs. Troy, of the Exchequer standard. The beam turned with 6 grs. when loaded with 30 pounds in each scale. Hence, supposing the pound averdupois to weigh 7000 grs. Troy, a cubic foot of water weighs $62\frac{1}{2}$ pounds averdupois, or 1000 ounces averdupois, wanting 106 grains Troy. And hence, if the specific gravity of water be called 1000, the proportional specific gravities of all other bodies will nearly express the number of averdupois ounces in a cubic foot. Or more accurately, supposing the specific gravity of water expressed by 1. and of all other bodies in proportional numbers, as the cubic

* The whole of this and the following article was communicated to the Translator by Professor Robison.—T.

cubic foot of water weighs, at the above temperature, exactly 437489.4 grains Troy, and the cubic inch of water 253.175 grains, the absolute weight of a cubical foot or inch of any body in Troy grains may be found by multiplying their specific gravity by either of the above numbers respectively.

By Everards experiment, and the proportions of the English and French Foot, as established by the Royal Society and French Academy of Sciences, the following numbers are ascertained.

Paris grains in a Paris cube foot of water - -	=645511
English grains in a Paris cube foot of water - -	=529922
Paris grains in an English cube foot of water - -	=533247
English grains in an English cube foot of water - -	=437489.4
English grains in an English cube inch of water -	=253.175
By an experiment of Picard with the measure and weight of the Chatelet, the Paris cube foot of water contains of Paris grains	=641326
By one of Du Hamel, made with great care - -	=641376
By Homberg - -	=641666

These

These ſhew ſome uncertainty in meaſure or in weights; but the above computation from Everards experiment may be relied on, becauſe the compariſon of the foot of England with that of France was made by the joint labour of the Royal Society of London and the French Academy of Sciences: It agrees likewiſe very nearly with the weight aſſigned by Mr Lavoiſier, 70 Paris pounds to the cubical foot of water.

No. X.

TABLES *for Converting Ounces, Drams, and Grains, Troy, into Decimals of the Troy Pound of* 12 *Ounces, and for Converting Decimals of the Pound Troy into Ounces, &c.*

I. *For Grains.*

Grains	= Pound.	Grains	= Pound.
1	.0001736	100	.0173611
2	.0003472	200	.0374222
3	.0005208	300	.0520833
4	.0006944	400	.0694444
5	.0008681	500	.0868055
6	.0010417	600	.1041666
7	.0012153	700	.1215277
8	.0013889	800	.1388888
9	.0015625	900	.1562499
10	.0017361	1000	.1736110
20	.0034722	2000	.3472220
30	.0052083	3000	.5298330
40	.0069444	4000	.6944440
50	.0086806	5000	.8680550
60	.0104167	6000	1.0418660
70	.0121528	7000	1.2152770
80	.0138889	8000	1.3888880
90	.0156250	9000	1.5624990

II.

II. *For Drams.*

Drams =	Pound.
1	.0104167
2	.0208333
3	.0312500
4	.0416667
5	.0520833
6	.0625000
7	.0729167
8	.0833333

III. *For Ounces.*

Ounces =	Pound.
1	.0833333
2	.1666667
3	.2500000
4	.3333333
5	.4166667
6	.5000000
7	.5833333
8	.6666667
9	.7500000
10	.8333333
11	.9166667
12	1.0000000

IV.

IV. *Decimals of the Pound into Ounces, &c.*

Tenth parts.			
lib. =	*oz.*	*dr.*	*gr.*
0.1	1	1	36
0.2	2	3	12
0.3	3	4	48
0.4	4	6	24
0.5	6	0	0
0.6	7	1	36
0.7	8	3	12
0.8	9	4	48
0.9	10	6	24
Hundredth parts.			
0.01	0	0	57.6
0.02	0	1	55.2
0.03	0	2	52.8
0.04	0	3	50.4
0.05	0	4	48.0
0.06	0	5	45.6
0.07	0	6	43.2
0.08	0	7	40.8
0.09	0	8	38.4
Thousandths.			
0.001	0	0	5.76
0.002	0	0	11.52
0.003	0	0	17.28
0.004	0	0	23.04
0.005	0	0	28.80

Thousandths.	
lib. =	*grs.*
0.006	34.56
0.007	40,32
0.008	46.08
0.009	51.84
Ten thousandth parts.	
0.0001	0.576
0.0002	1.152
0.0003	1.728
0.0004	2.304
0.0005	2.880
0.0006	3.456
0.0007	4.032
0.0008	4.608
0.0009	5.184
Hundred thousandth parts.	
0.00001	0.057
0.00002	0.115
0.00003	0.173
0.00004	0.230
0.00005	0.288
0.00006	0.346
0.00007	0.403
0.00008	0.461
0.00009	0.518

No.

No. XI.

TABLE *of the English Cubical Inches and Decimals corresponding to a determinate Troy weight of distilled Water of the Temperature of* 55°, *calculated from Everards Experiment*

For Grains.

Grs.	Cubical Inches.
1 =	.0039
2	.0079
3	.0118
4	.0158
5	.0197
6	.0237
7	.0276
8	.0316
9	.0355
10	.0395
20	.0790
30	.1185
40	.1580
50	.1974

For Drams.

Drams.	Cubical Inches.
1 =	.2370
2	.4739
3	.7109
4	.9479
5	1.1849
6	1.4219
7	1.6589

For Ounces.

Oz.	Cubical Inches.
1 =	1.8959
2	3.7918
3	5.6877
4	7.5837
5	9.4796
6	11.3755
7	13.2714
8	15.1674
9	17.0633
10	18.9592
11	20.8551

For Pounds.

Libs.	Cubical Inches.
1 =	22.7510
2	45.5021
3	68.2531
4	91.0042
5	113.7553
6	136.5063
7	159.2574
8	182.0084
9	204.7595
10	227.5106
50	1137.5530
100	2275.1061
1000	22751.0615

No. XII. Additional.

Table *of the Comparative Heats of different Bodies, as ascertained by Crawford.*

Hydrogen gas - -	21.4000
Oxygen gas - -	4.7490
Atmospheric air - -	1.7900
Steam or aqueous vapour -	1.5500
Carbonic acid gas - -	1.0454
Arterial blood - -	1.0300
Water - -	1.0000
Cows milk - -	.9999
Venous blood - -	.8928
Azotic gas - -	.7936
Hide of an ox with the hair -	.7870
Lungs of a sheep - -	.7690
Muscular flesh of an ox - -	.7400
Alcohol - -	.6021
Rice - -	.5060
Horse beans - -	.5020
Spermaceti oil - -	.5000
Fruit of the pine tree - -	.5000
Pease - -	.4920
Wheat - -	.4770

Barley

Barley - -	.4210
Oats - -	.4160
Sulphuric acid - -	.4290
Pitcoal - -	.2771
Charcoal - -	.2631
Chalk - -	.2564
Ruſt of iron - -	.2500
Waſhed diaphoretic Antimony -	.2272
Oxyd of copper nearly freed from air	.2272
Quicklime - -	.2229
Cinders - -	.1923
Aſhes of pitcoal - -	.1855
Ruſt of iron nearly freed from air	.1666
Waſhed diaphoretic Antimony do.	.1666
Aſhes of elm wood - -	.1402
Oxyd of Zinc nearly freed from air	.1369
Iron - -	.1269
Braſs - -	.1123
Copper - -	.1111
White oxyd of tin almoſt free of air	.0990
Zinc - -	.0943
Aſhes of charcoal - -	.0909
Tin - -	.0704
Yellow oxyd of lead almoſt free of air	.0680
Antimony - -	.0645
Lead - -	.0352

No.

No. XIII. Additional.

Table *of the Ingredients in Neutral Salts, as determined by Kirwan.*

	Acid	Alk.	Water
Sulphuric potaſh	31	63	6
Sulphuric ſoda	14	22	64
Sulphuric ammoniac	42	40	18
Nitric potaſh	30	63	7
Nitric ſoda	29	50	21
Nitric ammoniac	46	40	14
Muriatic potaſh	30	63	7
Muriatic ſoda	33	50	17
Muriatic ammoniac	52	40	8
Boracic ſoda	34	17	47

Earthy Salts.

	Acid	Earth	Water
Sulphuric magneſia	24	19	57
Sulphuric argil	24	18	58
Nitric calx	33	32	35
Nitric magneſia	36	27	37
Carbonic ſtrontites	30	61	9

Metallic Salts.

	Acid	Metal	Water
Sulphuric Iron	20	25	55
Do. Copper	30	27	43
Do. Zinc	22	20	58

No. XIV.

New Syſtem of Chemical Characters, adapted to the New Nomenclature, by Meſſrs Haſſenfratz and Adet: with ſome Alterations by the Tranſlator *.

The utility of chemical characters for many purpoſes has been long and univerſally acknowledged. Till of late they were perfectly arbitrary; and, from that circumſtance, even in the narrow limits of chemiſtry a few years ago, were difficultly retained in the memory. In the preſent highly advanced and improving ſtate of the ſcience, when an immenſe number of chemical ſubſtances have been added, and are daily diſcovering, the number of characters, neceſſary for the purpoſes of the chemiſt, has become ſo large that it is hardly poſſible

* Firſt added in this fifth Edition.—T.

ſible to remember them accurately, if continued on their former plan. Fully convinced of this, Meſſrs Haſſenfratz and Adet of Paris have, with great judgment and ingenuity, contrived a ſet characters, which are extremely diſtinct and ſimple, and require only to be ſeen once to be fully underſtood and perfectly remembered.

I have thought that it might be of conſiderable uſe to add theſe characters to the tranſlation of Mr Lavoiſiers Elements; and, though I acknowledge the excellence of the ſymbols invented by theſe gentlemen, I have taken the liberty to make ſome very ſlight alterations, by which they are rendered ſtill more ſimple and of eaſier application.

Meſſrs Haſſenfratz and Adet, beſides the general character for the metals in their ſimple ſtate, in which they are combuſtible bodies capable of oxydation and of oxygenation, have added different characters for azot, hydrogen, carbon, ſulphur and phoſphorus, which in their ſimple ſtate are likewiſe combuſtible bodies, ſuſceptible of being oxydated and oxygenated. From that ſtriking coincidence, I have rejected the peculiar characters of theſe latter ſubſtances, and ranked the whole known combuſtible, oxydable, and acidifiable ſimple ſubſtanſtances under one general character.

The only other difference, which indeed ariſes out of the one juſt mentioned, between the ſym-

bols of Messrs Hassenfratz and Adet, and those here given, is in the compound characters, which indicate the different states of aggregation, and various degrees of oxydation of the above five simple combustible substances.

In Table XIV. are engraved the whole characters that are necessary in the present state of chemistry. As chemistry advances towards perfection, these, instead of needing to be increased in number, may probably be still farther retrenched. The general character for unknown or little known and compound acidifiable bases (5.) will become unnecessary when these are ascertained. The figure at present used for representing non-acidifiable compound substances, or rather such substances when considered independently of oxydation, or acidification, will likewise become useless when the nature and composition of these bodies are fully understood. One of the alkalies is already known to be a compound consisting of known simple elements, and the other two are strongly suspected, upon very good analogical grounds, of being likewise compound bodies; hence the character employed for them will soon become unnecessary. Of the five known earths, three have lately been detected as metallic oxyds, a fourth is suspected to be only a modification of the fifth, and that too there are some reasons for believing to be allied to the acidifiable bases: When these discoveries

and

and conjectures are verified by farther experiment, this character will fall likewife to be expunged. Thus, in beautiful conformity with the fimplicity of fcience, which increafes in proportion to the advancement of our knowledge, the more we know of chemiftry the fewer characters will be needed for expreffing all its known fubftances.

Explanation of the Characters.

No. I. Fig. 1. The character for light, but which, in the prefent ftate of chemiftry, cannot be properly employed, as we are ignorant of the connection or difference between light and caloric.

Fig. 2. The fymbol of caloric, which in this new fet of fymbols is of fingular ufe for expreffing the different ftates of the aggregation of bodies.

Fig. 3. The fymbol for oxygen, which, by a very fimple contrivance, is made to indicate the various degrees of oxydation and acidification of all the bodies which are fufceptible of combination with oxygen.

Fig. 4. The general character for all combuftible, oxydable and acidifiable fubftances, confidered as fimple chemical elements.

Fig. 5. The general fymbol for all compound and unknown, or but little known oxydable and acidifiable bafes.

Fig. 6. reprefents all the non-acidifiable compound fubftances, or rather thefe confidered without any relation to oxygenation.

Fig. 7. reprefents the alkalies merely confidered as fuch.

Fig. 8. The fymbol for the earths confidered as elementary bodies, capable of entering into chemical combination; as if fimple, without their conftituent elements being decompounded.

Thefe laft five fymbols reprefent the whole known chemical fubftances by proper diftinctive marks, to be afterwards mentioned, except caloric and oxygen: In their fimple ftate, as at No. I., they muft all be confidered as indicating the folid ftate of the bodies they are meant to reprefent.

No. II. points out the method of employing the fymbol of caloric in conjunction with the characters of the other fubftances for indicating the various ftates of aggregation in thefe bodies. When the characters ftand fimple, the bodies muft univerfally be underftood as folid; the liquid ftate, when produced by caloric, or the fufion of the bodies by caloric, not folution by water, and the ftate of gas or vapour are mark- as under.

Fig. 1. A known fimple acidifiable fubftance in the liquid or fufed ftate.

Fig. 2. The fame fubftance in the ftate of gas.

Fig. 3

Fig. 3. A compound or unknown acidifiable base in the state of fusion or of liquefaction.

Fig. 4. The same in the vaporous state.

Fig. 5. A compound non-oxygenable substance in its liquid state.

Fig. 6. The same substance converted into gas.

Fig. 7. An alkali in the liquid state.

Fig. 8. An alkali in the state of vapour.

Fig. 9. An earth in fusion.

Fig. 10. The same raised in form of gas.

No. III. contains the application of the symbol of oxygen, for indicating the various degrees of oxydation and oxygenation of the substances capable of uniting with oxygen, and the changes in the states of aggregation produced on the resulting compounds by caloric. As before, they must be considered as solid, when the symbol of caloric is not united with them.

Fig. 1. A known simple base in the state of oxyd.

Fig. 2. The same base in the first or lower state of oxygenation, when the term for the acid ends in *osum* or *ous*.

Fig. 3. The same base saturated with oxygen, in which state the name of the acid ends in *icum*, or *ic*.

Fig. 4. The same base supersaturated with oxygen, when the acid is named superoxygenated.

Figs. 5, 6, 7. and 8. reprefent the above four degrees of oxydation and oxygenation in the liquid ftate.

Figs. 9, 10, 11. and 12. fhew the fame four degrees, as raifed to the ftate of gas.

Figs. 13, 14, 15. and 16. are the fymbols of the compound or unknown bafes in the fame four degrees of oxydation or oxygenation. It was thought unneceffary to add the fymbols of thefe in the liquid and gafeous ftates, as they are exactly analogous with the others.

No. IV. contains the fymbols of all the known combuftible, oxydable and acidifiable fimple fubftances, as folid, and neither oxydated nor acidified. From what has been already faid, it muft be perfectly obvious in what manner the fymbols of caloric and of oxygen are to be combined, to point out thefe fubftances in their liquid and vaporous ftates, and in their different degrees of oxygenation. The fymbol is the fame in all, and the fpecific differences are indicated by the initial letters of their Latin names, included within the character. Thus;

Fig. 1.	A.	*Azotum*,	Azote.
2.	C.	*Carbonum*,	Carbon.
3.	H.	*Hydrogenium*,	Hydrogen.
4.	S.	*Sulphurum*,	Sulphur.
5.	P.	*Phofphorum*,	Phofphorus.

Metals.

Metals.

Fig. 6.	Θ.	*Platinum,*	Platina.
7.	•	*Aurum,*	Gold.
8.	Ar.	*Argentum,*	Silver.
9.	Me.	*Mercurium,*	Mercury.
10.	St.	*Stannum,*	Tin.
11.	Cu.	*Cuprum,*	Copper.
12.	Pl.	*Plumbum,*	Lead.
13.	F.	*Ferrum,*	Iron.
14.	Z.	*Zincum,*	Zinc.
15.	Ma.	*Manganum,*	Manganefe.
16.	N.	*Niccolum,*	Nickel.
17.	An.	*Antimonium,*	Antimony.
18.	Co.	*Cobaltum,*	Cobalt.
19.	Ars.	*Arfenicum,*	Arfenic.
20.	Mo.	*Molybdum,*	Molybden.
21.	T.	*Tunftenum,*	Tunftein.

Newly difcovered Metals.

22.	Ca.	*Calcum,*	Metal of lime.
23.	Ba.	*Barytum,*	—— of barytes.
24.	Mg.	*Magnefium,*	—— of magnefia.

Thefe fymbols indicate the fimple and folid ftates of the fubftances they are ufed for expreffing; the liquid and gafeous ftates of each, and their various degrees of oxydation and oxygenation, are expreffed by means of the fymbols of caloric and oxygen, in the manner exemplified at No. II. and No. III.

No. V.

No. V. gives examples of compound ſymbols, for expreſſing the combinations which the above ſubſtances are capable of forming with each other, and with caloric or oxygen, or both.

Fig. 1. Azotic gas.
2. Azotic oxyd gas, or nitrous gas.
3. Solid nitrous, or azotous acid.
4. Solid nitric, or azotic acid.
5. Carbonic acid gas.
6. or 7. Oxyd of hydrogen, or water in the ſolid ſtate of aggregation, or ice.
8. Water, or ice fuſed by caloric.
9. Steam, or ice raiſed into vapour.
10. Solid azuret of carbon, or carburated azot. An unknown combination.
11. Carbonated azotic gas.
12. Carburet of hydrogen, or hydruret of carbon. Unknown, except as the baſe of ſome acids.
13. Carbonated hydrogen gas.
14. Carburet of iron.
15. Sulphuret of mercury.
16. Phoſphuret of iron.
17. Amalgam of mercury and gold.
18. Alloy of copper and tin.
19. Alloy of lead and tin.
20. Alloy of copper and zinc.

In

In the above inſtances, the combined ſubſtances are ſuppoſed to be in equal quantities, or at leaſt mutually ſaturated with each other; but the proportions of the ingredients to each other may, in a certain degree, be denoted by the relative arrangement of the ſymbols of theſe ingredients: When theſe are on the ſame horizontal line, as in the examples given at No. V. the ingredients, as has been already ſaid, are to be conſidered as in equal quantities, or mutually ſaturated; but when one ſymbol is placed over the other, the ingredient indicated by the lower muſt be conſidered as exceeding the other ingredient of the compound in quantity, or as not being fully ſaturated. Some examples of this are given in No. VI.

Fig. 1. Alloy of gold and copper, the gold being in larger quantity.

2. Silver alloyed with a ſmaller quantity of copper.

3. Alloy of ſilver with a ſmaller quantity of gold.

4. Alloy of gold with a ſmaller quantity of platina.

5. Alloy of tin, copper and lead in equal quantities.

6. Alloy of ſilver, gold and copper, the ſilver in largeſt proportion, the gold ſmaller, the copper leaſt of all.

Fig. 7.

Fig. 7. Alloy of tin and lead in equal quantities, with a fmaller proportion of zinc.

8. Copper and zinc, in equal quantities, alloyed with fmaller equal quantities of tin and lead.

9. Carburet of iron, in which the carbon is in larger quantity. Plumbago.

10. Carburet of iron, in which the carbon is in fmaller quantity. Steel.

11. Equal quantities of zinc and tin, alloyed with a larger portion of lead.

12. Equal quantities of zinc and copper, with a larger proportion of lead, and a fmaller of tin, alloyed together.

In No. VII. the general character ufed for denoting the unknown or compound, or but little known, oxydable and acidifiable bafes, is employed with proper diftinctive central marks for expreffing each of thefe bafes in particular. So many examples of the ufe of caloric and oxygen for indicating the ftates of aggregation, and degrees of faturation with oxygen, have been already given, that it is unneceffary to repeat them with thefe.

Fig. 1. M. Muria. The unknown radical or bafe of muriatic acid.

2. A M. Azo-muria. The compound bafe of the Nitro-muriatic or Azo-muriatic acid.

Fig. 3.

Fig. 3.	A.	Baſe of acetic and acetous acids.
4.	O.	——— oxalic acid.
5.	T.	——— tartaric acid.
6.	P T.	——— pyro-tartarous acid.
7.	Ci.	——— citric acid.
8.	Ma.	——— malic acid.
9.	P L.	——— pyro-lignous acid.
10.	P M.	——— pyro-mucous acid.
11.	G.	——— gallic acid.
12.	P.	——— pruſſic acid.
13.	Be.	——— benzoic acid.
14.	Su.	——— ſuccinic acid.
15.	Ca.	——— camphoric acid.
16.	La.	——— lactic acid.
17.	S L.	——— ſaccho-lactic acid.
18.	Bom.	——— bombic acid.
19.	Fo.	——— formic acid.
20.	Se.	——— ſebacic acid.
21.	Bor.	——— boracic acid.
22.	Fl.	——— fluoric acid.
23.	Li.	——— lithic acid.

The ſymbols for expreſſing the particular alkalies and earths, conſidered merely as ſuch, are contained at No. VIII. They muſt be underſtood as pure, and free from any combination whatever.

Fig. 1. *Lixa* or *potaſſa*. Potaſh.
2. *Trona* or *ſoda*.

Fig. 3.

Fig. 3. *Ammona* or ammoniac.
4. Ditto, confidered as relative to its ingredients, forming hydruret of azot, or azuret of hydrogen.
5. The fame in its vaporous ftate.
6. Baryta.
7. Calca, or lime.
8. Magnefia.
9. Arga, alumine or argil.
10. Silica or filex.

In No. IX. are contained the fymbols for denoting the falts, compofed of acids united with alkaline earthy or metallic bafes. Thefe may be confidered under three feparate heads; fuch as have the acid and alkali exactly faturated, in which cafe the fymbols of the ingredients are ranged on the fame horizontal line; fuch as have one of the ingredients in excefs, the fymbol of which is placed below the other; and fuch as confift of more than two ingredients. When the falt is fuppofed to be in a liquid ftate from caloric, or what is called in fufion, the fymbol of caloric is added upwards; when in the vaporous ftate, the fame character is made to point downwards; and when diffolved in any particular liquid, as water, the fymbol of the liquid is placed in the fame horizontal line, when a faturated folution, and below the line if the folvent be in excefs. Cryftallization,

ſtallization, or at leaſt ſolidity with water of cryſtallization united, may be expreſſed by the character of ice placed above the compound ſymbol expreſſing the ſalt. All theſe circumſtances are ſo very ſimple, and eaſily underſtood, that a very ſmall number of examples in each caſe may ſuffice.

Fig. 1. Carbonic lixa, or carbonat of potaſh, ſolid.
2. Sulphurous trona, or ſulphat of ſoda, fuſed.
3. Ammoniacal muriat, or muriatic ammona, in the vaporous ſtate.
4. Azotic or nitric lixa, or nitrat of potaſh, diſſolved to ſaturation in water.
5. Phoſphat of ſoda, or phoſphoric trona, in a ſolid ſtate with water of cryſtallization.
6. Muriatic mercury, or mercurial muriat, diſſolved in exceſs of water.
7. Fluoric calca, or calcareous fluor, ſolid.
8. Pyro-mucous baryta, or barytic pyromucite.
9. Azotous or nitrous magneſia, or magneſian nitrite.
10. Acidulous ſulphat of alumine, or acidulous ſulphuric arga.
11. Acidulous ſulphuric lixa.

Fig. 12.

Fig. 12. Alkaline ſulphuric trona.
13. Antimoniated tartarous lixa.
14. Ammoniated muriatic copper.
15. Phoſphoric trona and ammona, or fuſible ſalt of urine.
16. Muriatic mercury and ammona, or ſalt of wiſdom.

In No. X. are given a few examples of the combinations of the alkalies and earths with ſome of the other bodies conſidered as ſimple.

Fig. 1. Sulphuret of lixa, or ſulphurated lixa.
2. Sulphuret of calca, or ſulphurated lime, or calcareous ſulphuret.
3. Lixated ſilica in equal quantities.
4. Tronated ſilica, or glaſs; or ſuper-ſilicated trona.
5. Super-tronated ſilica, or ſoluble glaſs.

Such of the non-acidifiable compound ſubſtances as are thought neceſſary to be diſtinguiſhed by particular names, for chemical purpoſes, have their particular ſymbols repreſented at No. XI.

Fig. 1. Ether.
2. Alcohol.
3. Fixed vegetable oil.
4. Volatile oil, produced by diſtillation.

Fig. 5.

Fig. 5. Bitumen.
6. Mucus.
7. Starch.
8. Wax, cerum.
9. Aromatic oil.
10. Tannin.

Such other ſymbols as may be required for ſimilar ſubſtances, may be readily formed on this model.

In No. XII. ſome examples of the combinations of theſe laſt ſubſtances, with a few of thoſe formerly mentioned, are given.

Fig. 1. Soap of lixa, or lixivial ſoap; ſolid.
2. Sulphurated volatile oil, or balſam of ſulphur; liquid.
3. Calcareous ſoap; ſolid.
4. Emplaſter, or wax and oil in equal quantities; ſolid.
5. Proof ſpirit, or alcohol and water, in equal quantities.
6. Weak ſpirit, or alcohol mixed with a larger proportion of water.
7. Lead plaſter, or fixed oil, united to an equal quantity of oxyd of lead; ſolid.

Fig. 8. Drying oil, or fixed oil united with a ſmaller portion of oxyd of lead; liquid.

9. Ammoniacal ſoap; the oil in larger proportions; liquid.

10. Unguent, or wax mixed with a larger quantity of oil.

ADDEN-

ADDENDA*.

§ 1. *Of Columbium, a new Metal.*

THE mineral ſubſtance from which this new metal has been procured, ſeems to have long lain neglected ; as it is ſaid to have been ſent to Sir Hans Sloane from Maſſachuſets in America. From the place of its origin, its diſcoverer, Mr Hatchet, has very properly given it the name here adopted.

 This

* Since the firſt volume of this edition was printed off, the tranſlator has had acceſs to the knowledge of ſeveral new chemical diſcoveries, which are here detailed, and for which he is chiefly indebted to Thomſons Syſtem of Chemiſtry.—T.

This American mineral was confidered formerly as a refractory ore of iron, but is now proved to be a metallic falt, confifting of oxyd of iron combined with a peculiar acid. It is of a dark grey colour, with fome refemblance to chromat of lead, and has confiderable gravity. It is hardly foluble in any of the acids; except that fulphuric acid diffolves a fmall portion of the oxyd of iron, which enters into its compofition.

By alternately fufing this mineral with carbonat of potafh, lixiviating this with water, and digefting the remainder in muriatic acid, and repeating thefe proceffes in fucceffion, it is at laft completely diffolved and decompofed. In this decompofition, the peculiar acid unites with the potafh, from which it expels the carbonic acid; and the new neutral falt, with bafe of potafh, is diffolved in the water. The muriatic acid diffolves the oxyd of iron.

The neutral falt is decompofed by nitric acid, which precipitates the peculiar acid in form of white flakes. This acid unites, both in the dry and humid way, with potafh and foda, from which it expels carbonic acid; and with potafh it forms a glittering fcaly falt, refembling boracic acid. It does not unite with ammonia. Thefe neutral falts are decompofed by moft of the other acids; and the precipitated acid is rediffolved

diſſolved by means of heat, if the precipitating acid is in exceſs, except by nitric acid. It is likewiſe rediſſolved by exceſs of alkali, when precipitated from its ſolution in acids, by potaſh or ſoda.

The white flakey precipitate, mentioned above, or the peculiar acid now under conſideration, is inſoluble in nitric acid, even with the aſſiſtance of heat, but readily diſſolves in ſulphuric and muriatic acids; and is precipitated from either of theſe ſolutions, in its white flakey form, by potaſh. From the ſolution of the neutral ſalts of this acid, when aſſiſted by the preſence of an acid, pruſſiat of potaſh gives an olive green precipitate, and tincture of galls a precipitate of a deep orange colour. From theſe circumſtances, its metallic nature is inferred, as it does not appear to have been hitherto reduced to the metallic form. Mr Hatchet, therefore, has choſen to call this new acid the Columbic Acid; and the metal, which he ſuppoſes to form its radical, he calls Columbium. The mineral ſubſtance from which it is procured, is therefore a columbat of iron; and, by his experiments, is compoſed of 75 parts in the 100 of columbic acid, and 25 parts of oxyd of iron.

When the ſolution of columbic acid by ſulphuric acid is diluted with water, the columbic

 acid,

acid precipitates of a white colour: This, on drying, changes firft to blue, and afterwards to grey. It is likewife precipitated of a white colour, from its folution in fulphuric acid by zinc. The acid folutions of columbic acid, and the folutions of its neutral falts, are colourlefs.

By hydro-fulphuret of ammonia, a chocolate coloured precipitate is thrown down, from columbat of potafh or foda. With phofphat of ammonia, columbic acid melts into a purplifh blue glafs. It does not combine with fulphur.

§ 2. *Of Gafeous Oxyd of Carbon**.

This gas was firft formed in the experiments of Dr Prieftley; but remained long confounded with carbonated hydrogen gas, under the denomination of Heavy inflammable air, until examined by Mr Cruickfhank, and afterwards by Berthollet, Fourcroy, and other French chemifts.

Carbonic

* This gas might very properly be termed Oxy-carbonic Gas.—T.

Carbonic oxyd gas is procured by a variety of processes. By exposing moistened charcoal, or mixtures of charcoal and metallic oxyds, or charcoal and earthy carbonats, to a red heat in iron-tubes or earthen-retorts, and receiving the gas in a pneumato-chemical apparatus; or by passing carbonic acid gas repeatedly through red hot charcoal. In these processes, the gaseous product should be made to pass through a very thin paste of quick-lime and water, on purpose to absorb the carbonic acid, which comes over along with the carbonic oxyd gas.

This gas is permanently elastic. When breathed, it produces giddiness and fainting: It instantly kills animals, and does not support combustion. Mixed with atmospheric air, or oxygen gas, it burns with a lambent blue flame, and the product is carbonic acid. It is not altered by light, heat or electricity, or by passing through a red-hot tube, even along with ammonia. It is not acted on by azot or sulphur, even with the assistance of heat. It is not changed by the alkalies. Its specific gravity is .001167, being lighter than atmospheric air, in the proportion of 22 to 23.

Phosphorus is dissolved in this gas, and the solution burns with a yellow flame. It likewise dissolves a small portion of charcoal, and thereby increases somewhat in volume: Indeed

it would appear that carbon is ſuſceptible of ſeveral degrees of oxydation, in the permanent ſtate of gas; or, in other words, that the proportions of oxygen and carbon, in the carbonic oxyd gas, is ſubject to variety.

When equal meaſures of carbonic oxyd gas and hydrogen gas are made to paſs through a red-hot glaſs-tube, the oxyd is decompoſed; the charcoal is depoſited like a fine black enamel on the inner ſurface of the tube, water is formed, and an exceſs of hydrogen gas eſcapes. If, in this experiment, a ſmall piece of iron be placed in the tube, it becomes oxydated.

According to the experiments of Mr Cruickſhank, 100 parts of carbonic oxyd gas conſiſt of 26 parts of carbon, united to 74 parts of oxygen; though it appears, from what has been ſaid above, not to be regular and permanent in the proportions of its elements. By the ſame experiments, and thoſe of the French chemiſts, it appears that charcoal, formerly by Lavoiſier conſidered as pure carbon, with a minute portion of aſhes, conſiſts of 64.3 parts of pure carbon, with 35.7 of oxygen; and is, therefore, a ſolid oxyd of carbon. Carbonic acid, according to theſe lateſt experiments, conſiſts of 18 parts of carbon, and 82 parts of oxygen: Or, as in the following Table:

	Carbon.	Oxygen.
Charcoal, or ſolid carbonic oxyd	= 100	+ 55.5
Gaſeous oxyd of carbon	= 100	+ 307.7
Carbonic acid gas	= 100	+ 455.5

§ 3. *Of Gaſeous Oxyd of Azot* *.

Azot, like carbon, is ſuſceptible of combining with two different portions of oxygen, in the ſtate of oxyd. Both of theſe have been long known, from the diſcoveries of Dr Prieſtley, by the names of Nitrous gas, and Dephlogiſticated nitrous gas; but the latter, of which we mean to give ſome account in this place, has only very lately been accurately examined by Mr Davy.

Gaſeous oxyd of azot is procured by expoſing cryſtals of nitrat of ammonia, in a retort, to a heat not leſs than 340° nor above 500° of Fahrenheit. The nitrat ſoon melts, and is decompoſed, giving out oxyd of azot, which is to be

* Oxy-azotic Gas, would be a very regular term for this new gas.—T.

be collected in a pneumato-chemical apparatus. It is permanently elaſtic, but heavier than atmoſpheric air, in the proportion nearly of 5 to 3, having the ſpecific gravity of .00197. It ſupports combuſtion better than common air, even almoſt as well as oxygen gas; but combuſtibles muſt previouſly be ignited to make them burn in this gas. Animals live in it for ſome time, apparently without uneaſineſs; they ſoon, however, ſhew ſigns of reſtleſſneſs, and die if not removed in a few minutes.

Azotic oxyd gas is readily abſorbed by water in conſiderable quantity, eſpecially when aſſiſted by agitation, and the water acquires a ſweetiſh taſte: During the abſorption of this gas, the atmoſpheric air uſually contained in the water is expelled. The whole of the azotic oxyd gas is expelled from water, altogether unchanged, by means of boiling. It is not altered by atmoſpheric air, or oxygen gas; nor by light. Neither is it changed by any heat below ignition; but when made to paſs through a red-hot tube, or when electric ſparks are taken in this gas, the arrangement of its elements is altered, and it is changed into nitric acid, oxygen gas, and azotic gas.

Combuſtible ſubſtances are unchanged by expoſure to this gas in the uſual temperature; but all of them that have been tried decompoſe it

by

by combuſtion. If ſulphur that is burning with a white flame, be plunged into azotic oxyd gas, it continues to burn with a brilliant red flame, till half of the oxyd is decompoſed ; the products are ſulphuric acid and azot. Phoſphorus may be melted and ſublimed in this gas without change, and will not even burn when touched by a red-hot wire. But if touched with a wire heated to whiteneſs, it inſtantly takes fire, and explodes with violence ; the products are phoſphoric acid, nitric acid, and azot. Charcoal may be kindled in this oxyd by a burning glaſs, and burns with great brilliancy till half of the gas is decompoſed ; the products are carbonic acid and azot. Hydrogen gas, and ſulphurated, phoſphorated, and carbonated hydrogen gas, mixed with azotic oxyd gas, explode violently, either by means of the electric ſpark, or by a ſtrong red heat. Iron-wire burns as readily in it as in oxygen gas. Zinc likewiſe burns in it. It is unneceſſary to particularize all the products of theſe combuſtions.

Azotic oxyd gas, at the moment of its formation, may be made to combine with the alkalies, forming ſalts of a peculiar nature, which have not hitherto been very attentively examined. Theſe are certainly not neutral ſalts, there being no acid preſent ; and we have nothing yet quite analogous to them in chemiſtry, though

they

they may be ſaid to approach the nature of ſulphurets, phoſphurets, and carburets. Mr Davy propoſes to give them the name of *nitroxis*, and Dr Thomſon prefers the term of Azotites. They might be denominated Oxy-azurets.

By the experiments of Mr Davy, it appears that 100 parts of gaſeous oxyd of azot contain 63 parts of azot and 37 parts of oxygen; while nitrous gas contains only 45 parts of azot in the 100, united to 55 parts of oxygen.

The moſt extraordinary properties of gaſeous oxyd of azot, are its effects on mankind when reſpired. It may be breathed for near four minutes without danger; but after that it puts a ſtop to all voluntary motions. Mr Davy thus deſcribes its effects on himſelf:

" Having cloſed my noſtrils, and exhauſted my
" lungs, I breathed four quarts of nitrous oxyd
" from and into a ſilk bag. The firſt feeling was
" giddineſs; but in leſs than half a minute, that
" diminiſhed gradually, and was ſucceeded by a
" ſenſation analogous to gentle preſſure on all
" the muſcles, attended by a highly pleaſurable
" thrilling, particularly in the cheſt and extremi-
" ties. The objects around me became dazzling,
" and my hearing more acute. Towards the laſt
" inſpirations, the thrilling increaſed, the ſenſe
" of muſcular power became greater, and at laſt
" an irreſiſtible propenſity to action was indul-

" ged

" ged in. I recollect but indistinctly what fol-
" lowed. I know that my motions were various
" and violent. These effects very soon ceased
" after respiration of the gas was discontinued.
" In ten minutes I had recovered my natural
" state of mind. The thrilling in the extre-
" mities continued longer than the other sen-
" sations."

This gas has been breathed by many other persons: On most, similar effects to those described by Mr Davy, were produced; though some give an account highly poetical of the pleasurable sensations. A few people were not sensible of any particular effects; and on others the effects produced were uniformly painful and unpleasant. Upon the whole, the effects produced by breathing this gas are similar to intoxication; but they do not last, and leave no languor nor debility.

§ 4. *Of*

§ 4. *Of Laccic Acid.*

This acid, or acidulous ſubſtance, has been detected by Dr Pearſon, in a kind of wax or lac, produced in India by an inſect of the tribe coccus, firſt noticed by Dr Anderſon of Madras. This waxy ſubſtance, which Dr Anderſon calls white lac, when melting, gives out a reddiſh watery liquid, ſmelling like new-baked bread, and of a ſlightly ſaltiſh taſte, with ſome bitterneſs. This ſaline water is the laccic acid of Dr Pearſon.

Laccic acid gives a red colour to paper which is ſtained with turnſole. Its ſpecific gravity is 1.025. By evaporation, it depoſites a ſmall quantity of needle-like cryſtals. It may be diſtilled without alteration. It diſſolves carbonat of lime, or of ſoda, with effervеſcence. Three grains of carbonat of ſoda is ſufficient to neutralize five hundred grains of the laccic acid liquor: The ſaturated ſolution, after filtration and evaporation, affords deliqueſcent cryſtals.

From laccic acid liquor, lime-water occaſions a light purple turbid appearance; ſulphuret of lime, a white precipitate; tincture of galls, a green precipitate; ſulphat of iron, gives a

a purplifh colour, but no precipitate; acetite of lead, a reddifh precipitate; nitrat of mercury, a whitifh cloudinefs; oxalic acid, throws down white needle-like cryftals, probably from the liquid containing fome lime; tartarite of potafh gives a precipitate, fimilar to that produced on adding tartarous acid to tartarite of potafh.

FINIS.

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Scalpd ... Sculp.

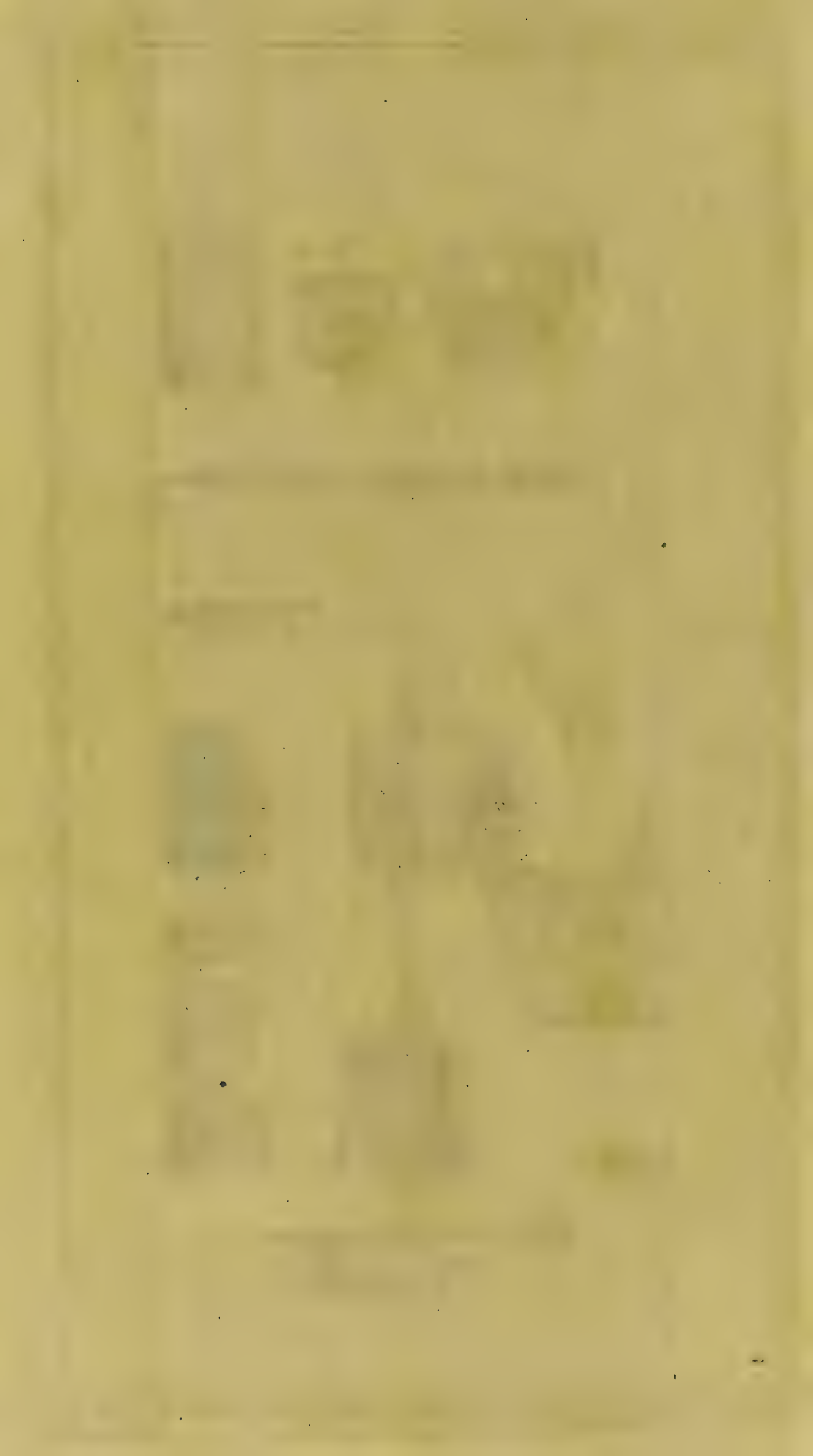
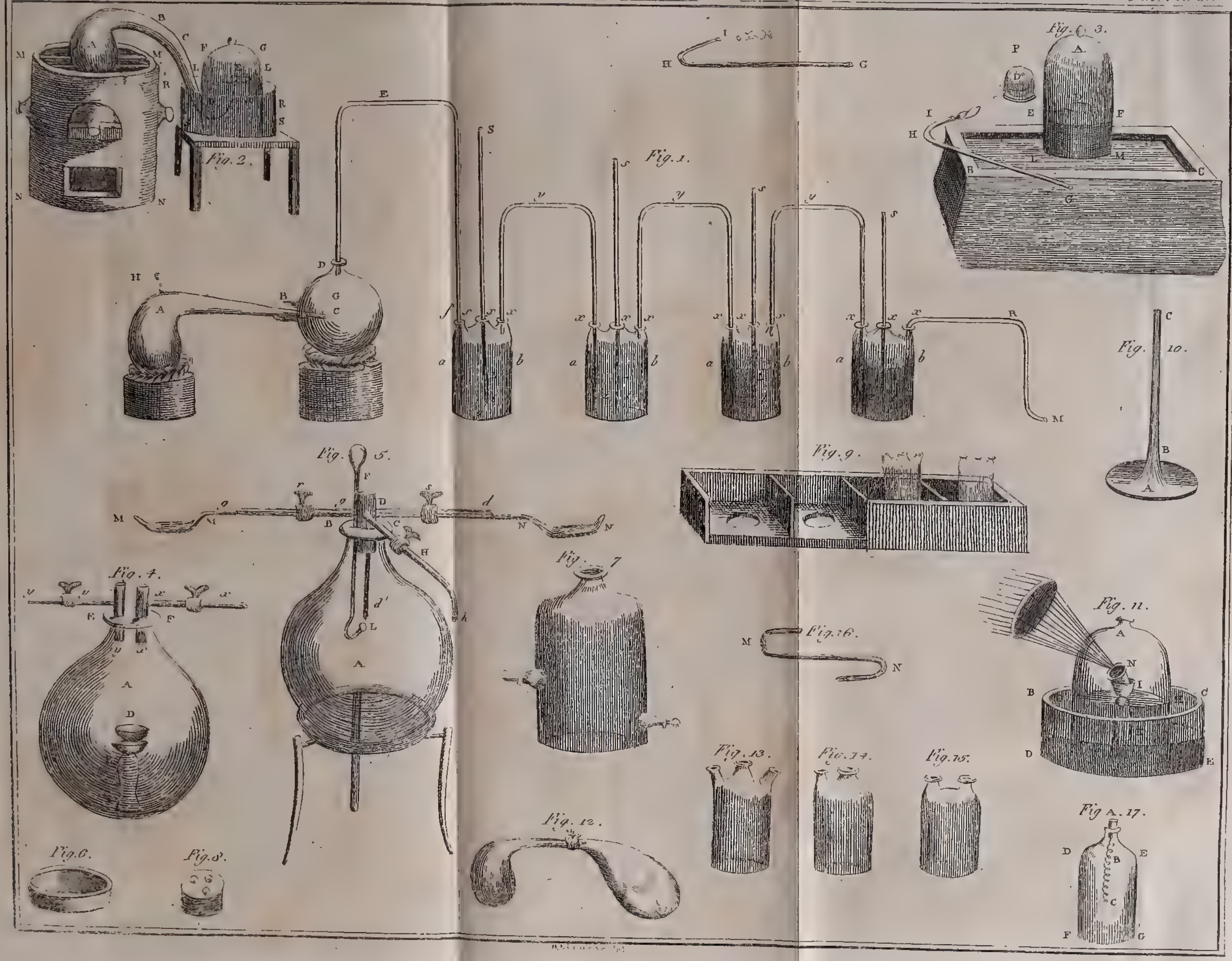



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Dixon's Sculp^t


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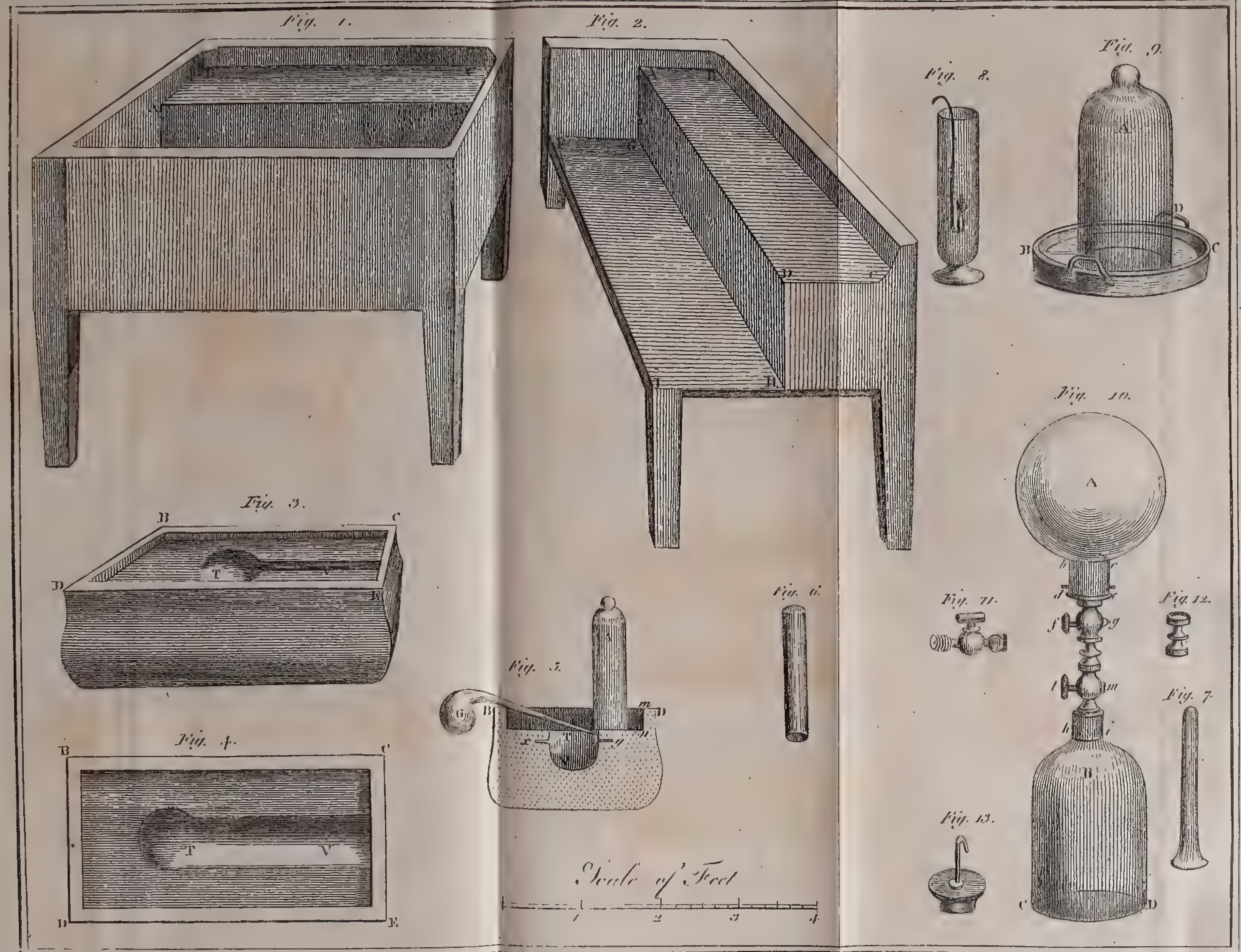

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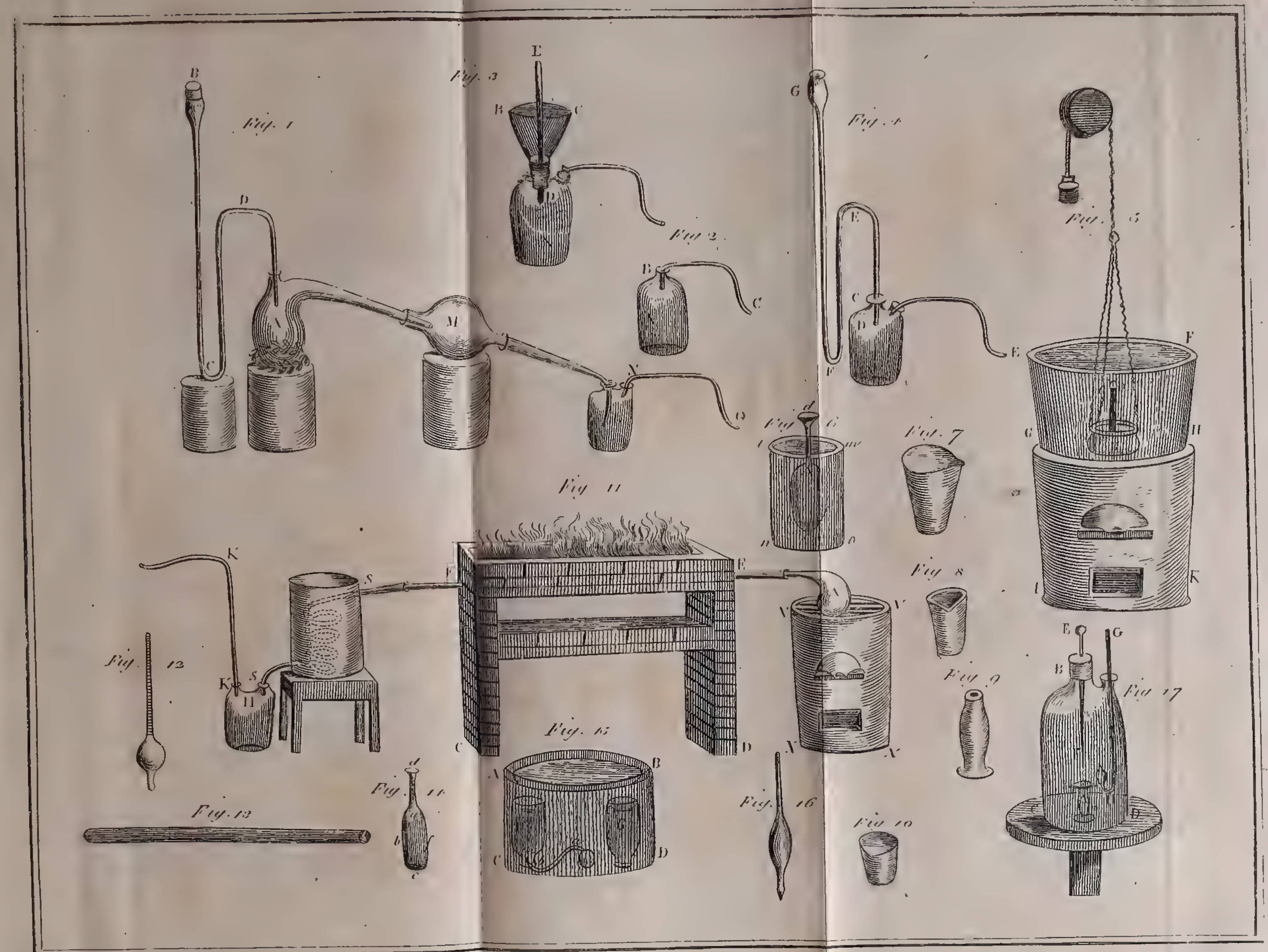

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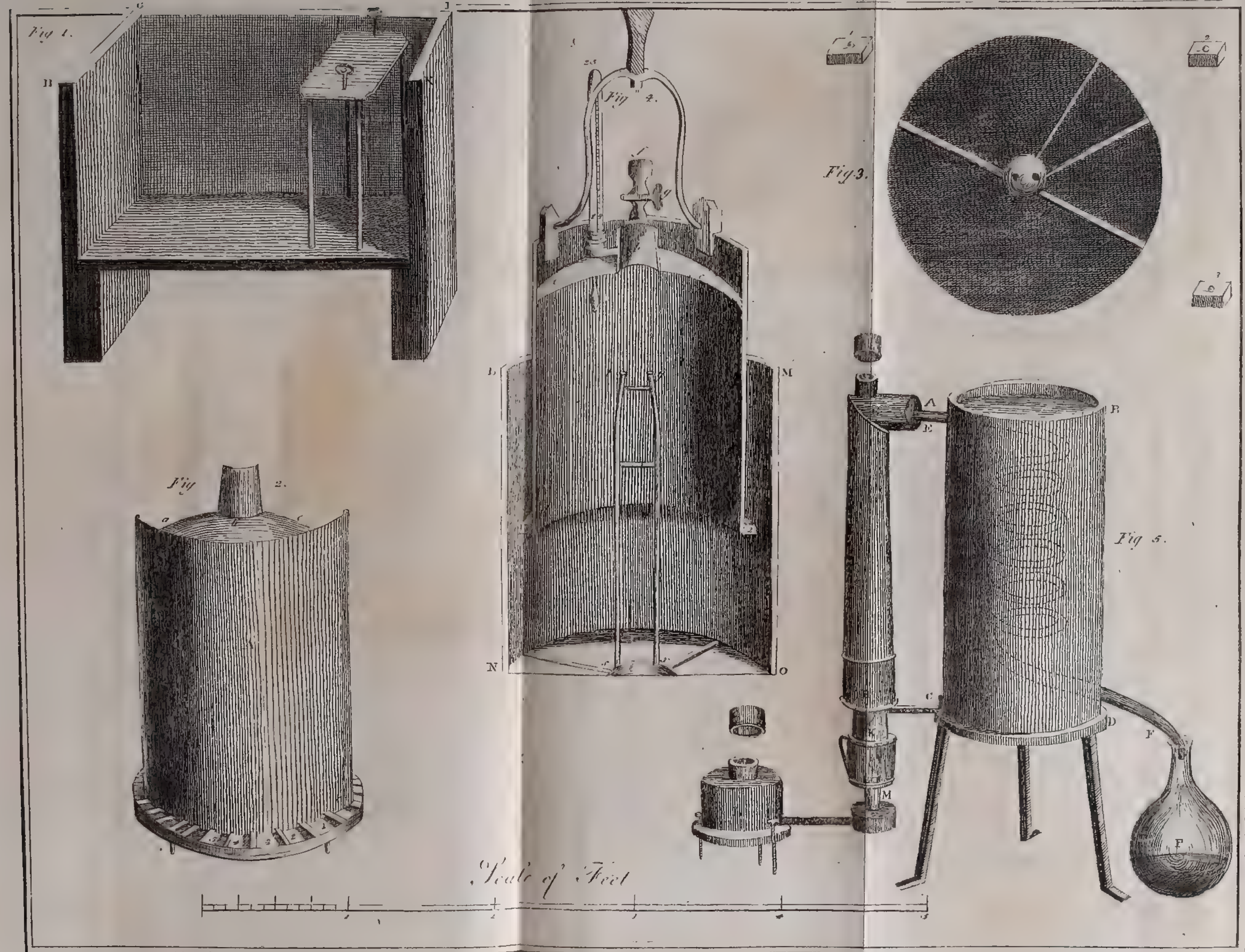
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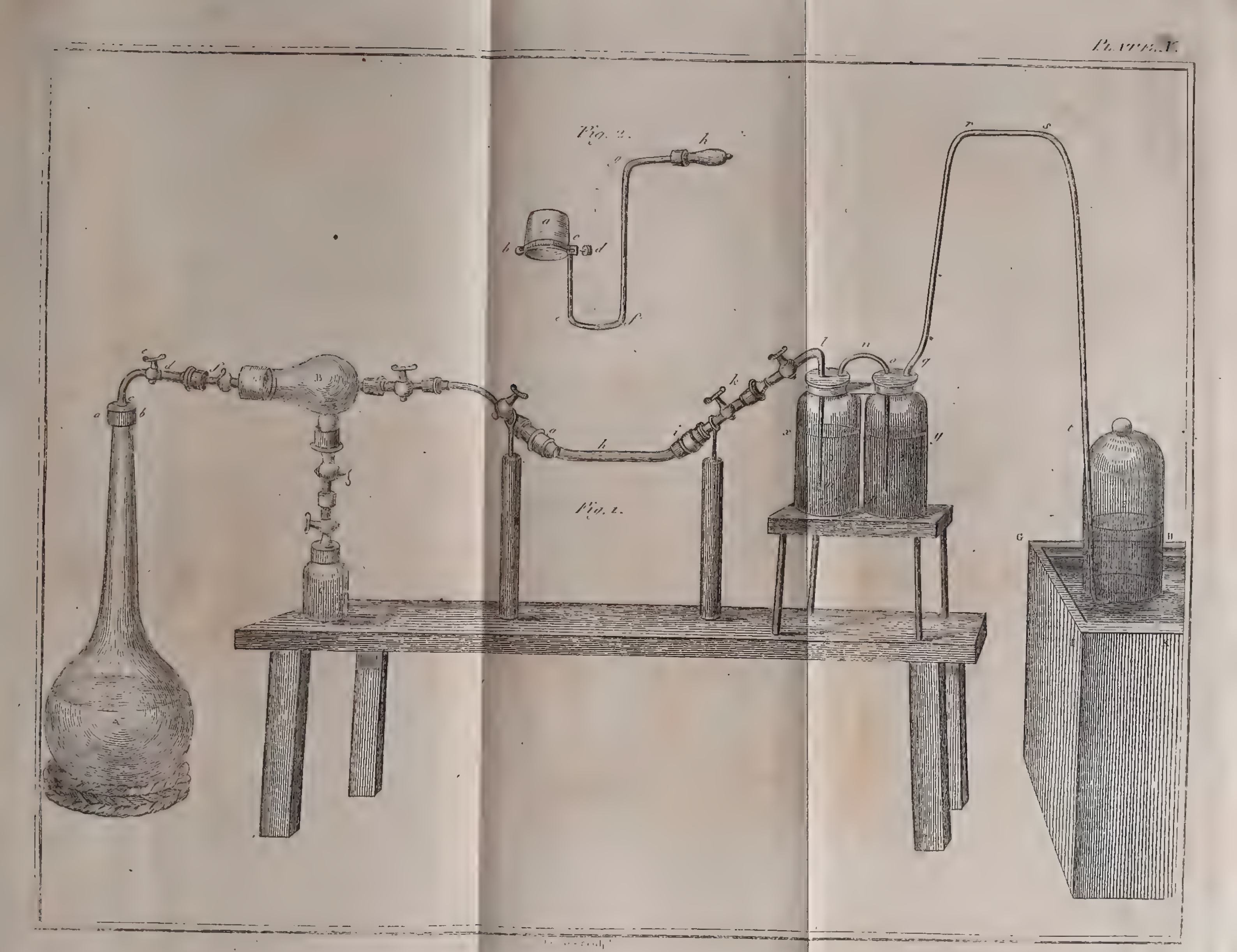
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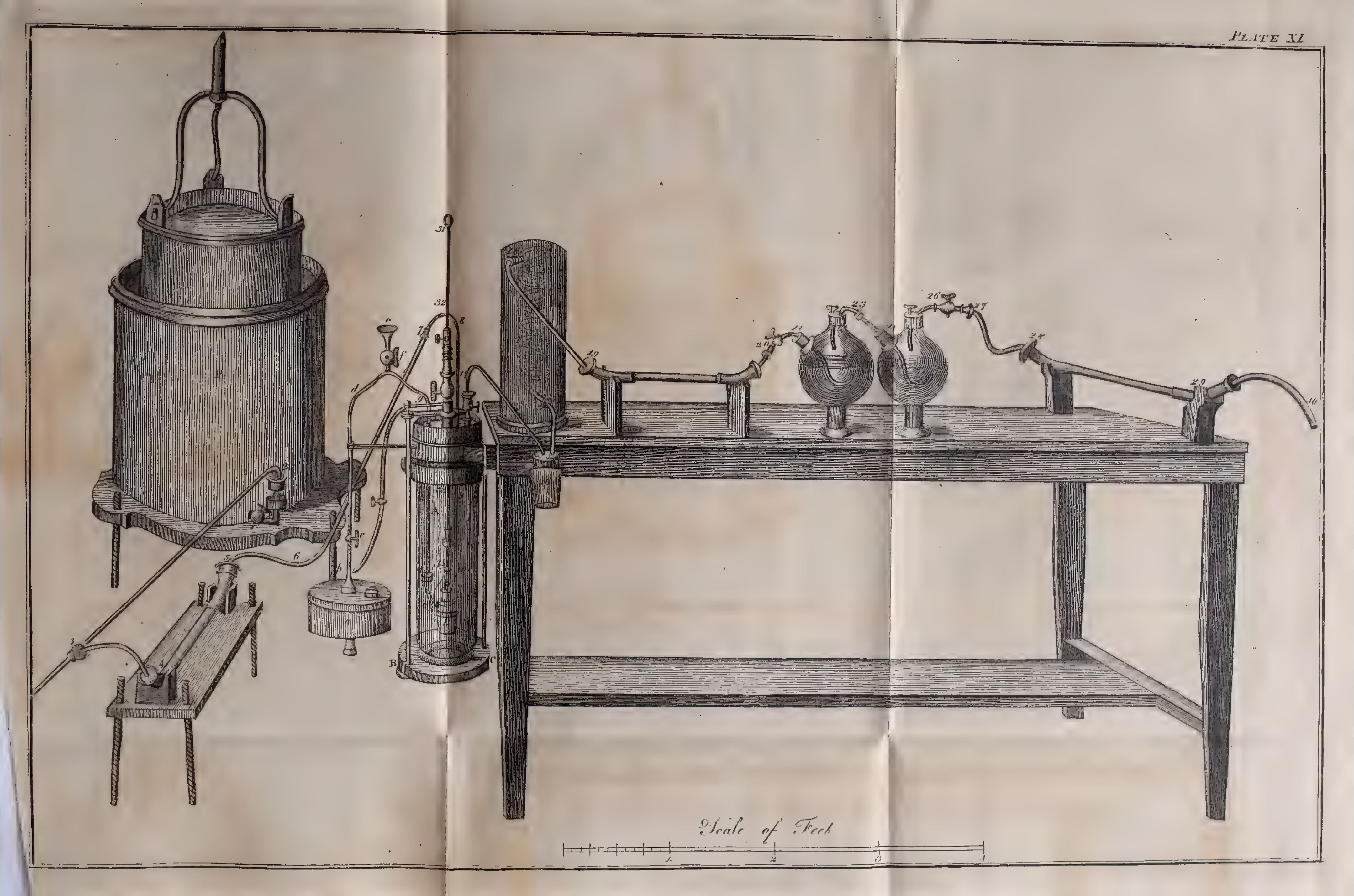
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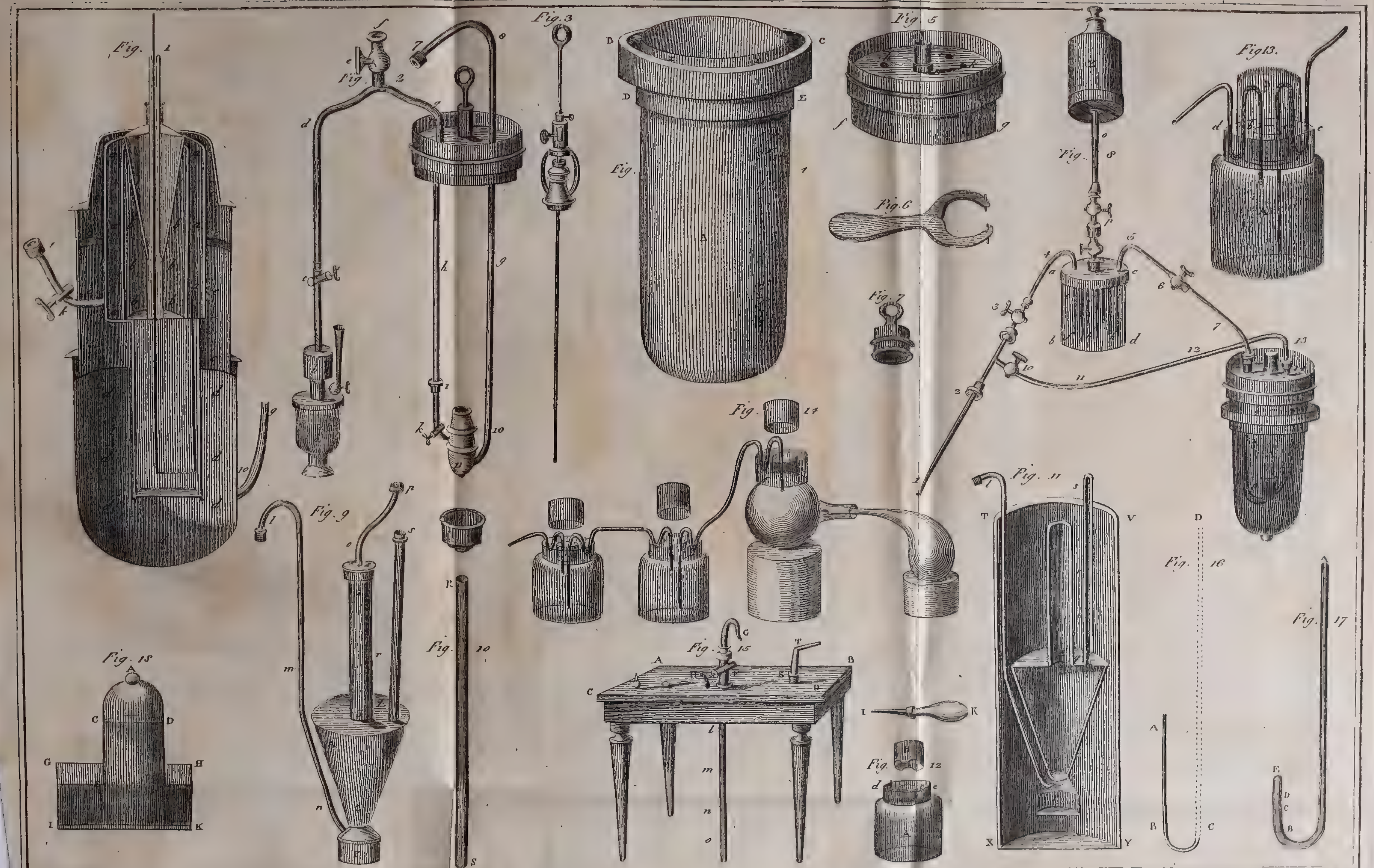
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D. Lizars Sculpt


Fig 1.
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Scale of Feet


Plate V.
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Fig. 1.


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D.Lizars Sculpt

Fig. 1

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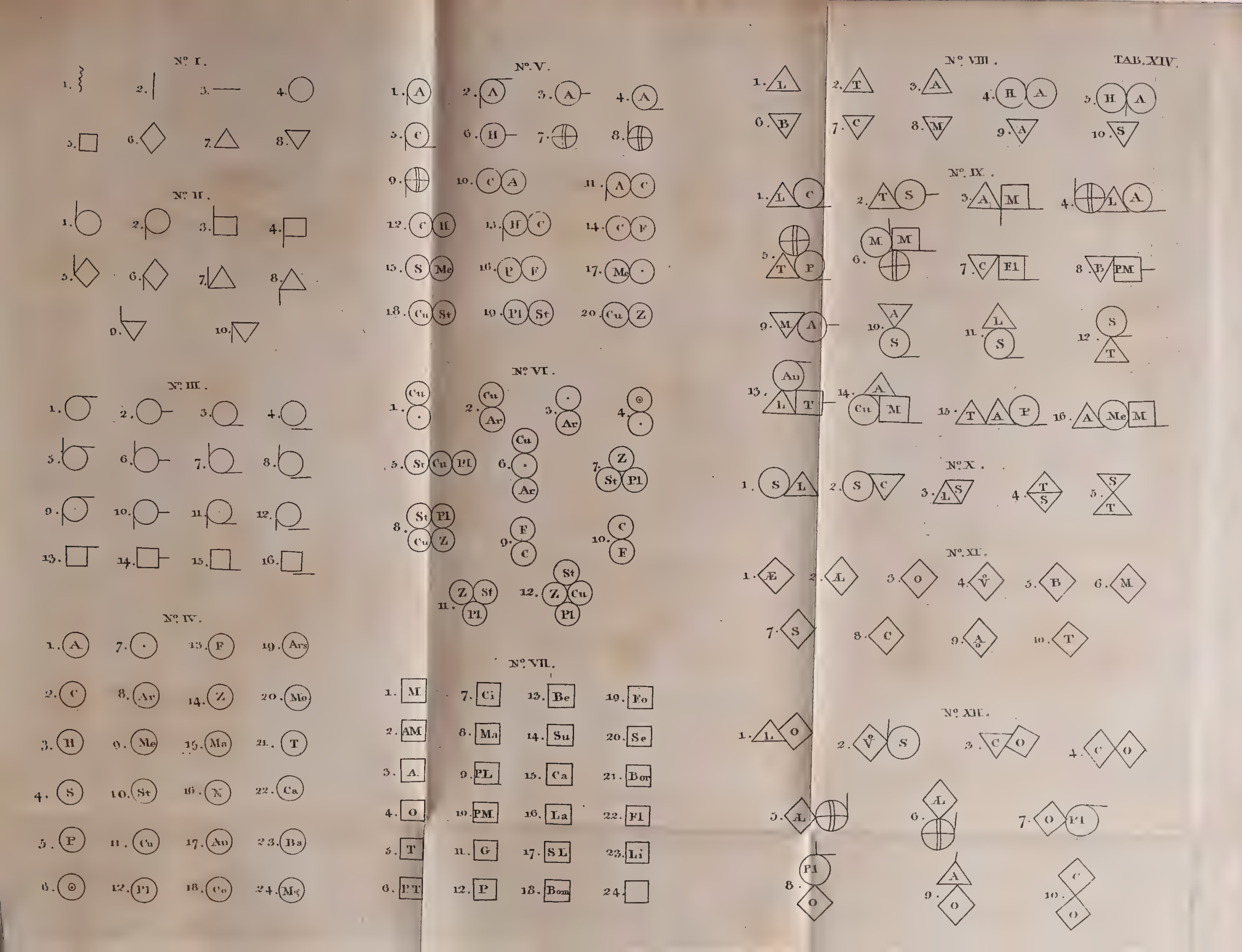
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